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SPACE STATION FURNACE FACILITY
Preliminary Project Implementation Plan (PIP)

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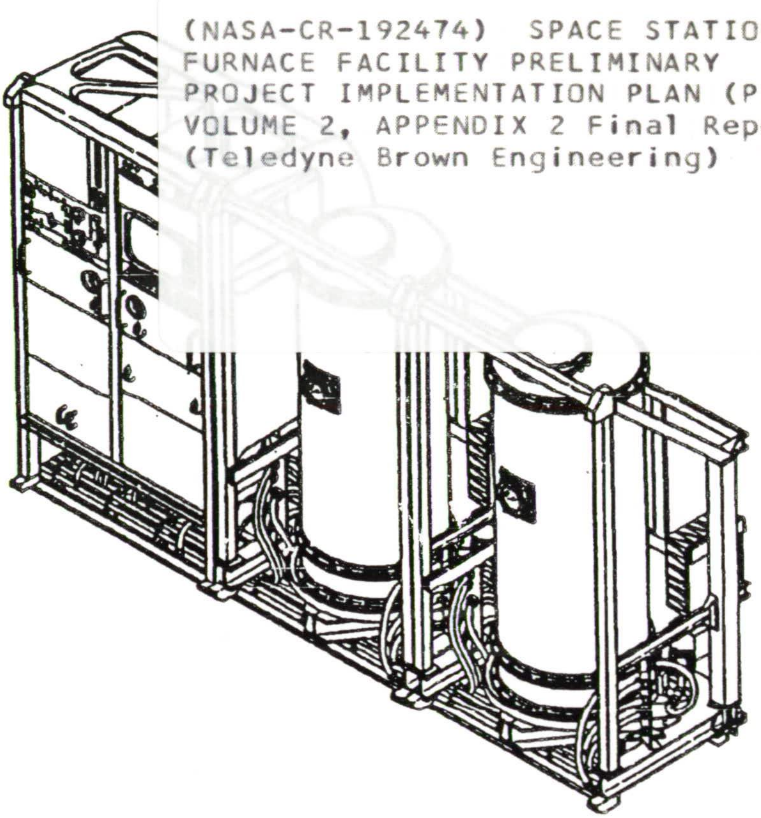

DR-4
May 1992

Volume II, Appendix 2
Final Study Report (DR-8) of
Space Station Furnace Facility
Contract No. NAS8-38077

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Sponsored by:	National Aeronautics and Space Administration Office of Space Science and Applications Microgravity Science and Applications Division Code SN Washington, D.C. 20546
Contracting Officer:	Craig C. Mitchell NASA/Marshall Space Flight Center
Contract Monitor:	Arthur S. Kirkindall NASA/Marshall Space Flight Center
Contract Number:	NAS8-38077
Contractor:	Teledyne Brown Engineering Cummings Research Park 300 Sparkman Drive, NW P. O. Box 070007 Huntsville, Alabama 35807-7007
Project Manger:	G. P. Jenkins
Project Engineer:	R. C. Seabrook

Prepared by:

John K. Perkey

John Perkey, Systems Engineer
SSFF

Prepared by:

Approved by:

Greg P. Jenkins

Greg P. Jenkins, Project Manager
SSFF

Approved By:

A. Sharpe, Manager
Advanced Programs Department

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ACRONYM LIST

Acronym	Meaning
A&I	Assembly and Installation
ATP	Authority to Proceed
C&T	Communications and Tracking
CAR	Certification/Acceptance Review
CCF	Centralized Core Functions
CCU	Core Control Unit
CDR	Critical Design Review
CDROM/WORM	Compact Disk Read Only Memory/Write Once Read Many
CEI	Contract End Item
CEO	Cheif Engineer's Office
CGF	Crystal Growth Facility
CJB-A	Core Junct Box -A
CJB-B	Core Junct Box -B
CM	Core Monitor
CM & CU	Core Monitor and Control Unit
CPC	Core Power Conditioner
CPD	Core Pwr Distributor
DCF ER1	Distributed Core Functions Experiment Rack 1
DCF ER2	Distributed Core Functions Experiment Rack 2
DDT&E	Design, Development, Test and Engineering
DMS	Data Management Subsystem
DR-4	Data Requirement Number 4
DR-5	Data Requirement Number 5
DR-6	Data Requirement Number 6
DR-7	Data Requirement Number 7
E/FRD	Experiment/Facility Requirements Document
EAC	Experiment Apparatus Container
EEE	Electrical Electronic and Electromechanical
EMI	Electromagnetic Interference
ER	Experiment Rack
ERD(s)	Experiment Requirement Document
ESA	European Space Agency
FAU	Furnace Actuator Unit
FCU	Furnace Control Unit
FDD	Flight Definition Document
FDDI	Fiber Distributed Data Interface
FDS	Fire Detection and Suppression
FJB	Furnace Junction Box
FM	Furnace Module
FM 1	Furnace Module 1
FM 2	Furnace Module 2
FOs	Functional Objectives
FPD	Furnace Power Distributor
FPE	Furnace Peculiar Equipment
FRR	Flight Readiness Review
GCEL	Ground Control Experiment Laboratory
GDS	Gas Distribution System
GSE	Ground Support Equipment
H/W	Hardware

HR	Hour
HRDL	High Rate Data Link
I/O	Input/Output
ICD	Interface Control Document
IFEA	Integrated Furnace Experiment Assembly
IPL	Integrated Payload
IPL-CDR	Integrated Payload Critical Design Review
IPL-FOR	Intregrated Payload Flight Operations Review
IPL-PDR	Integrated Payload Preliminary Design Review
IROP	Integrated Requirements on Payloads
IRR	Integrated Readiness Review
ISPR	International Standard Payload Rack
IWG(s)	Investigator Working Groups
JSC	Johnson Space Center
KG	kilograms
kPa	kiloPascals
KSC	Kennedy Space Center
KW	kilowatts
LNS	Lab Nitrogen System
MDM	Multiplexer/Demultiplexer
MIUL	Materials Identification and Usage List
MODB	Master Object Data Base
MSFC	Marshall Space Flight Center
MSS	Mechanical/Structural Subsystem
MST	Mission Sequence Tests
MUAs	Materials Usage Agreements
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
ORU	Orbital Replacement Unit
OSSA	Office of Space Science and Applications
PAH	Payload Accommodations Handbook
PAP	Payload Activity Planning
PCAP	Payload Crew Activity Plan
PCDS	Power Conditioning and Distribution Subsystem
PCS	Power Conditioning System
PDP	Production Data Products
PDR	Preliminary Design Review
PDS	Power Distribution System
PDSS	Payload Data Services System
PED(s)	Payload Element Developer(s)
PFDF	Payload Flight Data File
PI(s)	Principal Investigator(s)
PIA	Payload Integration Agreement
PIP	Project Implementation Plan
PMA	Performance Management and Administration
PMI	Periodic Maintenance Inspections
PMZF	Programmable Multi-Zone Furnace
POIC	Payload Operations and Integration Center
PRR	Preliminary Requirements Review
PTC	Payload Training Center
PTRD	Payload Trainer Requirements Documents
QD	Quick Disconnect
RPCM	Remote Power Control Modules
S&E	Science and Engineering

S/W	Software
SCRD	Science Capabilities and Requirements Document
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
SSFP	Space Station Freedom Program
STD	Standard
STS	Space Transportation System
TAR(s)	Trainer Acceptance Review(s)
TAT	Training Assessment Team
TBD	To Be Determined
TCS	Thermal Control Subsystem
TIMs	Technical Interchange Meetings
TOS	Training Operations Subpanel
UF-3	Utilization Flight 3
UF-7	Utilization Flight 7
UPTP	User Payload Training Plan
USL	United States Laboratory
VDC	Volts Direct Current
VES	Vacuum Exhaust System
VPU	Video Processor Unit
WBS	Work Breakdown Structure

1.0 INTRODUCTION

This Project Implementation Plan (PIP) document has been developed to satisfy the requirements of Data Requirement Number 4 (DR-4) for the Space Station Furnace Facility (SSFF) study (Phase B) performed under NASA Contract NAS8-38077. This PIP shall address the planning of the activities required to perform the detailed design and development of the SSFF for the Phase C/D portion of this contract.

1.1 SSFF DESCRIPTION

The SSFF is an advanced facility for materials research in the microgravity environment of the Space Station Freedom (SSF), and will consist of Core equipment and various sets of Furnace Module (FM) equipment in a three-rack configuration. The Core equipment will interface directly with the SSF resources and will consist of the hardware and software required to control and distribute the SSF resources to the FM equipment for the diverse range of requirements to be satisfied by the FMs. The FM equipment will interface with the Core equipment and will consist of the hardware and software to perform and characterize specific science functions based on science investigators' requirements inputs documented in the Science Capabilities and Requirements Document (SCRD), JA55-XXX. The design and development of the SSFF Core equipment and the SSFF FMs will take place under separate contracts.

The Phase B study portion of the SSFF contract included the identification of subsystem level SSFF Core equipment based on satisfying the requirements of the FM strawman configuration of the Crystal Growth Facility (CGF) and the Programmable Multizone Furnace (PMZF). The CGF and the PMZF strawman configuration enveloped most of the requirements in the SCRD and provided a source for mature design data for feasibility assessment during the Phase B study. Per the Phase B study, the major Core subsystems equipment will interface with the SSF resources and will be maintained in a SSFF-developed rack structure, which is equivalent to a Space Station International Standard Payload Rack (ISPR) structure. Core equipment will also be maintained in adjacent locations (Experiment Racks (ERs)) to allow the FM-to-Core equipment interface. The Core equipment that will be maintained in a central rack structure, including that equipment interfacing directly with SSF resources, will be considered "centralized" Core equipment. The Core equipment maintained in the adjacent ER structure locations will be considered "distributed" Core equipment. The FM equipment will be maintained in two ER structures adjacent to the centralized rack structure, and will interface with distributed Core

equipment. The three rack structures identified during the Phase B study for mounting Core equipment and FM equipment are unique rack structures due to the unique interface and structural requirements of the Core-to-SSF resources interfaces, and the FM-to-rack structure interfaces.

1.2 CONTRACT END ITEM (CEI) SPECIFICATION

The SSFF will ultimately be designed to meet the requirements of the Contract End Item (CEI) Specifications. The Preliminary CEI Specifications for the Core were developed under the Phase B contract effort as Data Requirement Number 7 (DR-7). This DR describes the subsystem level functional and performance criteria to which the SSFF and its support equipment will be designed and developed.

1.3 WORK BREAKDOWN STRUCTURE (WBS) SUMMARY

The remainder of this document will describe the work elements that apply to technical and programmatic requirements for implementing the Phase C/D development effort of the SSFF. The Work Breakdown Structure (WBS) lists the functions required to develop the SSFF during the Phase C/D effort. The major WBS elements and subelements are presented in Figure 1.0-1. The definitions of the WBS elements and subelements are discussed in Data Requirement Number 5 (DR-5), Work Breakdown Structure and WBS Dictionary. The WBS will provide the basis for planning, monitoring, performing, and reporting the SSFF development. The major WBS elements to be performed by contractors identified for the SSFF Phase C/D effort include the following:

- Design, Development, Test, and Engineering (DDT&E)
- Integration
- Training
- Operations
- Logistics

The Design, Development, Test, and Engineering (DDT&E) element will include the activities required to design, manufacture, procure, verify and test the SSFF hardware and software and supporting equipment and software. The activities incorporated into this element include design requirements review, interface definition review and support,

concept identification, concept trade studies and selection, SSFF design, Ground Support Equipment (GSE) identification and design, test equipment identification and design, training equipment design, design support documentation preparation, support facilities requirements identification, manufacturing activities and support, procurement activities and support, testing activities and support, analytical integration support, physical integration support, flight and mission operations support, verification activities, and review support.

The Integration element will include the activities required to analytically and physically integrate the SSFF hardware and software and its support equipment and software. The activities incorporated into this element include interface definition, interface documentation development and control, verification identification and definition, verification review and tracking, ground operations testing, assembly, integration, and checkout activities, and review support.

The Training element will include the activities required to sufficiently train the crew, the operations cadre, the Principal Investigators (PIs), and the SSFF developers in the familiarization and proficiency of experiment operations for the SSFF. The activities incorporated into this element include the identification of training activities, scheduling of training activities, training documentation preparation, training equipment (i.e., trainers/simulators) design requirements identification, coordination and performance of training events, and review support.

The Operations element will include the activities required to plan the usage of available resources and perform the specific functions to operate the SSFF hardware and software on-orbit. The activities incorporated into this element include the review of operations requirements, operations documentation preparation, timeline development, training support, integration support, data requirements analyses, compatibility assessments, flight operations control and monitoring, and review support.

The Logistics element will include the activities required to procure, distribute, maintain, and replace the hardware and software for each of the major SSFF elements (i.e., the Core, and the two FMs). The activities required to perform the functions of this element include planning of the hardware usage and flow between each developer, procurement of hardware components and software to support the design and fabrication of the Core and the FMs, coordinating the distribution and receipt of hardware and software items between each developer, maintaining hardware and software supply to support the refurbishment of SSFF elements and to support the parallel ground operations, determining and implementing packaging, handling, transportation, and storage for the SSFF elements as required, and providing review support for each of the major milestone reviews.

A management function is associated with each of the major WBS elements outlined in the previous paragraphs. The management activities associated with each element includes the development of project schedules, the control and planning of project financing, control of the specific element activities, performance monitoring, configuration control and planning, information control, facilities control and usage planning, control of subcontractors' inputs, performance monitoring of subcontractors, product assurance, project risks assessment, and provision of review support for each of the major milestone reviews.

The outline of the PIP will include not only descriptions of the individual developer activities described in the previous paragraphs, but also the NASA management, engineering labs functions, and the Principal Investigators (PIs) functions required to support the SSFF development. The outline of the remaining PIP sections in this document includes the following:

Section 2.0 - Applicable Documents
Section 3.0 - NASA Program Management
Section 4.0 - NASA Engineering and Test Labs
Section 5.0 - DDT& E
Section 6.0 - Integration
Section 7.0 - Training
Section 8.0 - Operations
Section 9.0 - Logistics
Section 10.0 - Principal Investigators
Section 11.0 - Risk Assessment Summary

1.4 PROGRAM COST ESTIMATE

All cost estimate information for the Phase C/D effort will be contained in Data Requirement Number 6 (DR-6), Program Cost Estimate.

1.5 GROUNDRULES AND ASSUMPTIONS

The activities identified in this PIP for the development of the hardware and software for each of the major SSFF articles will require the application of specific groundrules and assumptions. The Project Master Schedule depicting the major WBS

element activities, the major milestones/reviews, and interrelationships of the WBS elements based on these groundrules and assumptions is presented in Figure 1.0-2.

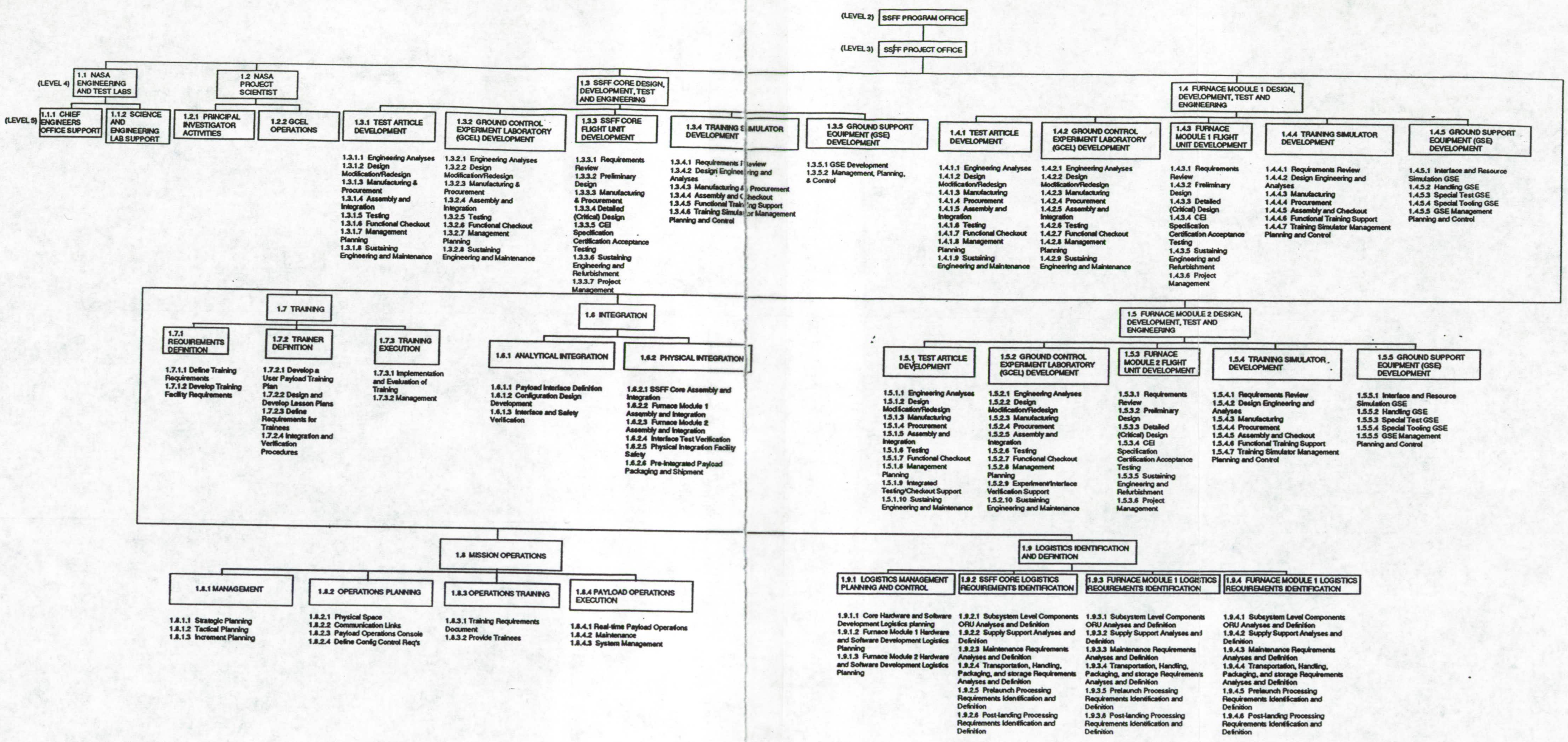


FIGURE 1.0-1 SPACE STATION FURNACE FACILITY (SSFF) WORK BREAKDOWN STRUCTURE

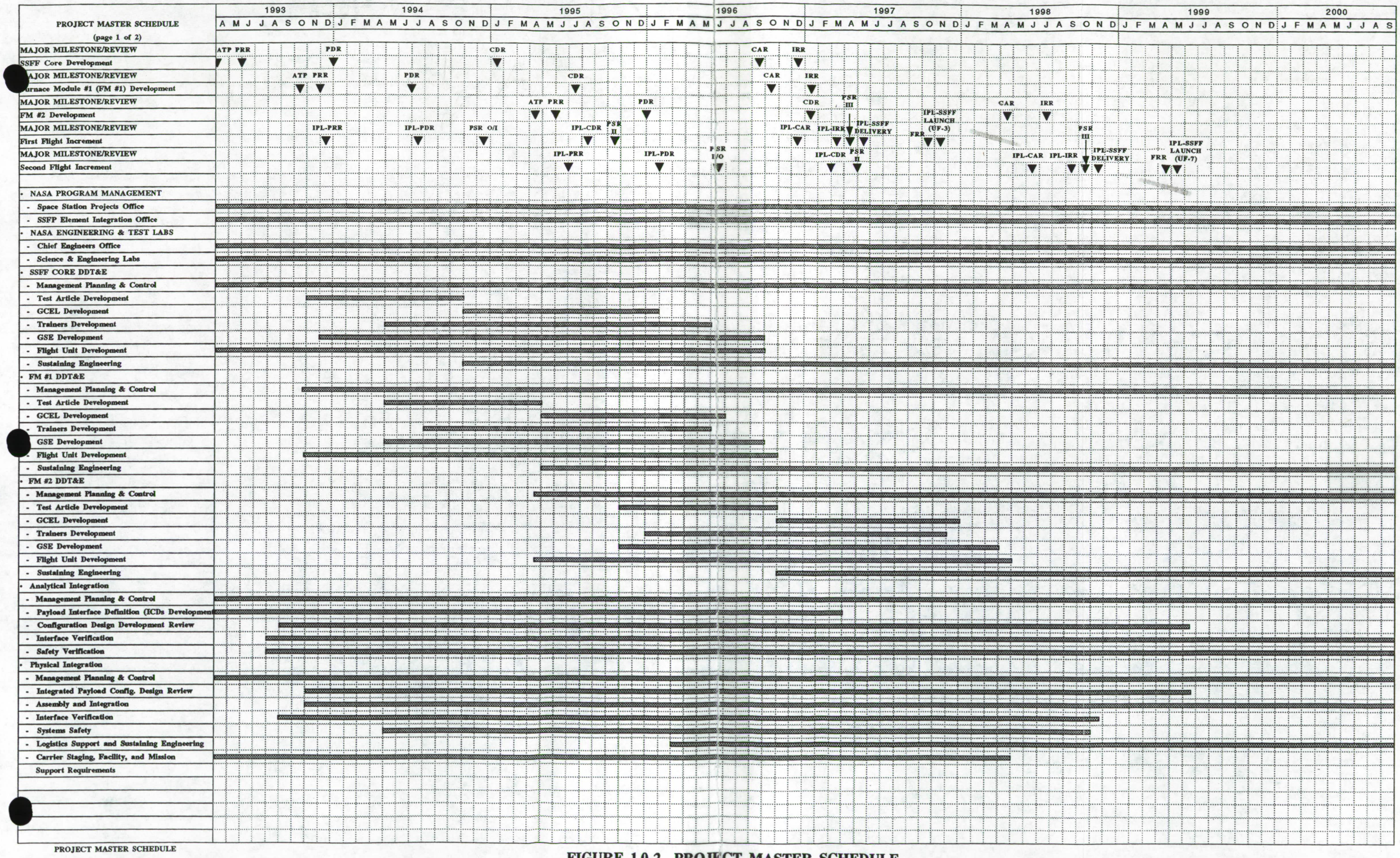


FIGURE 1.0-2 PROJECT MASTER SCHEDULE
(page 1 of 2)

FOLDOUT FRAME 1.

FOLDOUT FRAME 2.

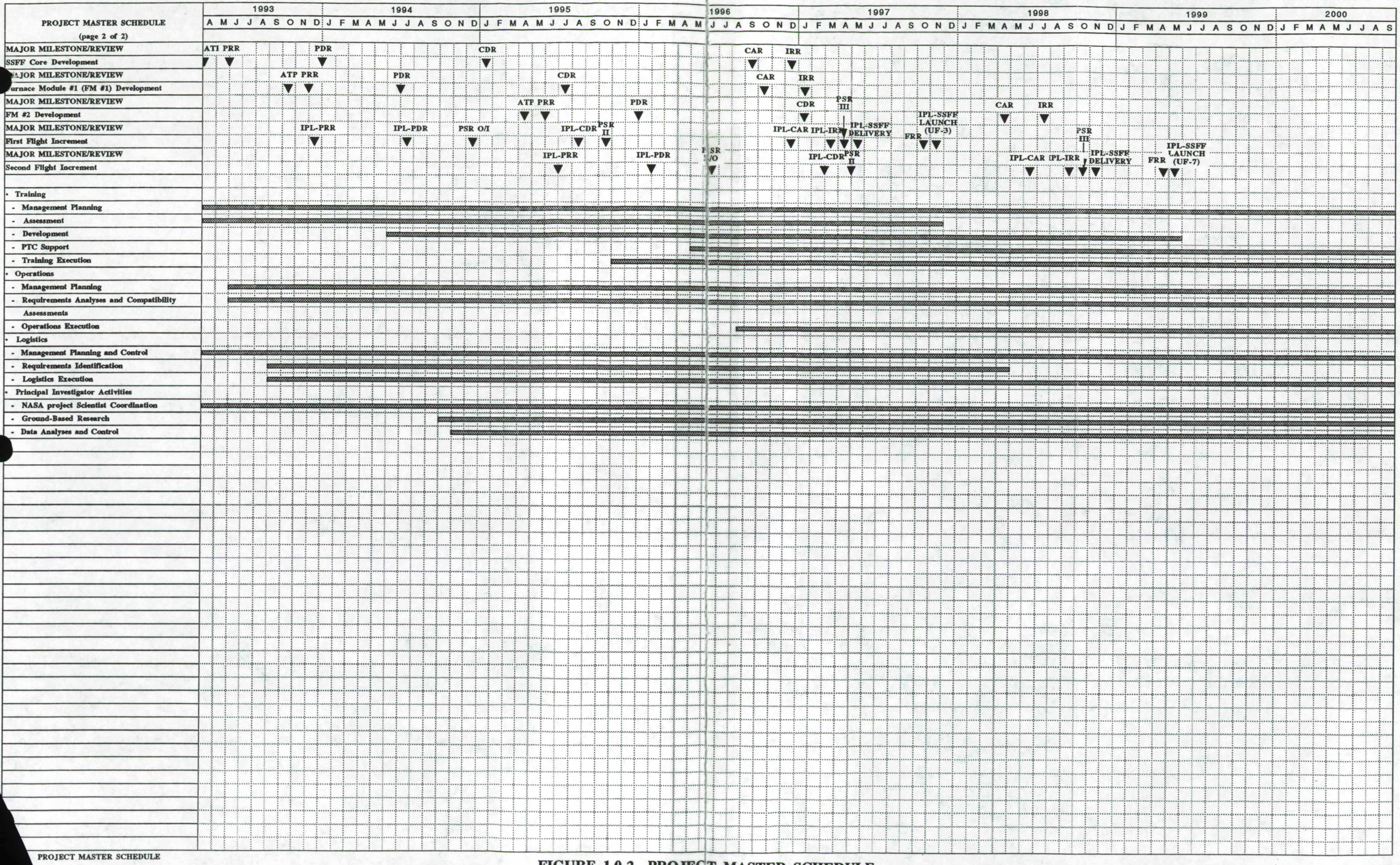


FIGURE 1.0-2 PROJECT MASTER SCHEDULE

(page 2 of 2)

FOLDOUT FRAME 1.

FOLDOUT FRAME 2

The groundrules and assumptions that pertain to the schedules and activities descriptions included in this PIP are presented in the following list:

- The SSFF Core flight equipment will consist of the following major articles for development by a single developer:
  - SSFF Core unique rack structure (one of three as described in the "Introduction").
  - All SSFF Core subsystem components to be located in the Core rack structure (centralized Core equipment).
  - All SSFF Core subsystem components to be located in the adjacent rack structures (distributed Core equipment).
  - Unique rack structures for FM accommodation (ERs - the remaining two of three rack structures).
- Each set of FM equipment will consist of furnace experiment assembly hardware (i.e., an EAC-type cannister containing the furnace components, and the internal data management equipment, control equipment, power conditioning and distribution equipment, and thermal control equipment).
- The three-rack configuration of the SSFF (described in the Introduction) will be integrated in the United States Laboratory (USL) module of the SSF in two increments.
  - The first flight increment will consist of the SSFF Core centralized and distributed equipment and one set of FM equipment, in a two-rack configuration. One rack structure will be considered Core centralized equipment, which will contain the other Core centralized components, and the other ER structure will be considered Core distributed equipment, which will contain the Core distributed equipment and the FM equipment.
  - The second flight increment will consist of the second set of FM equipment in a ER structure. The ER structure will be Core distributed equipment.

- The launch date for the first flight increment to which all schedules are identified is November, 1997. This is Utilization Flight 3 (UF-3).

- The launch date for the second flight increment is May, 1999. This is Utilization Flight 7 (UF-7).

- The Core equipment, FM 1 equipment, and FM 2 equipment will be developed under separate programs.

- The SSFF Core equipment and the FM 1 equipment will be delivered to KSC as a pre-integrated payload (two rack complement consisting of the integrated Core rack and an integrated ER) for the first flight increment.

- The integration of the SSFF Core equipment and the FM 1 equipment will be performed at the SSFF MSFC Core developer's proposed integration and checkout facility to allow the pre-integration and checkout of the payload prior to shipment to KSC.

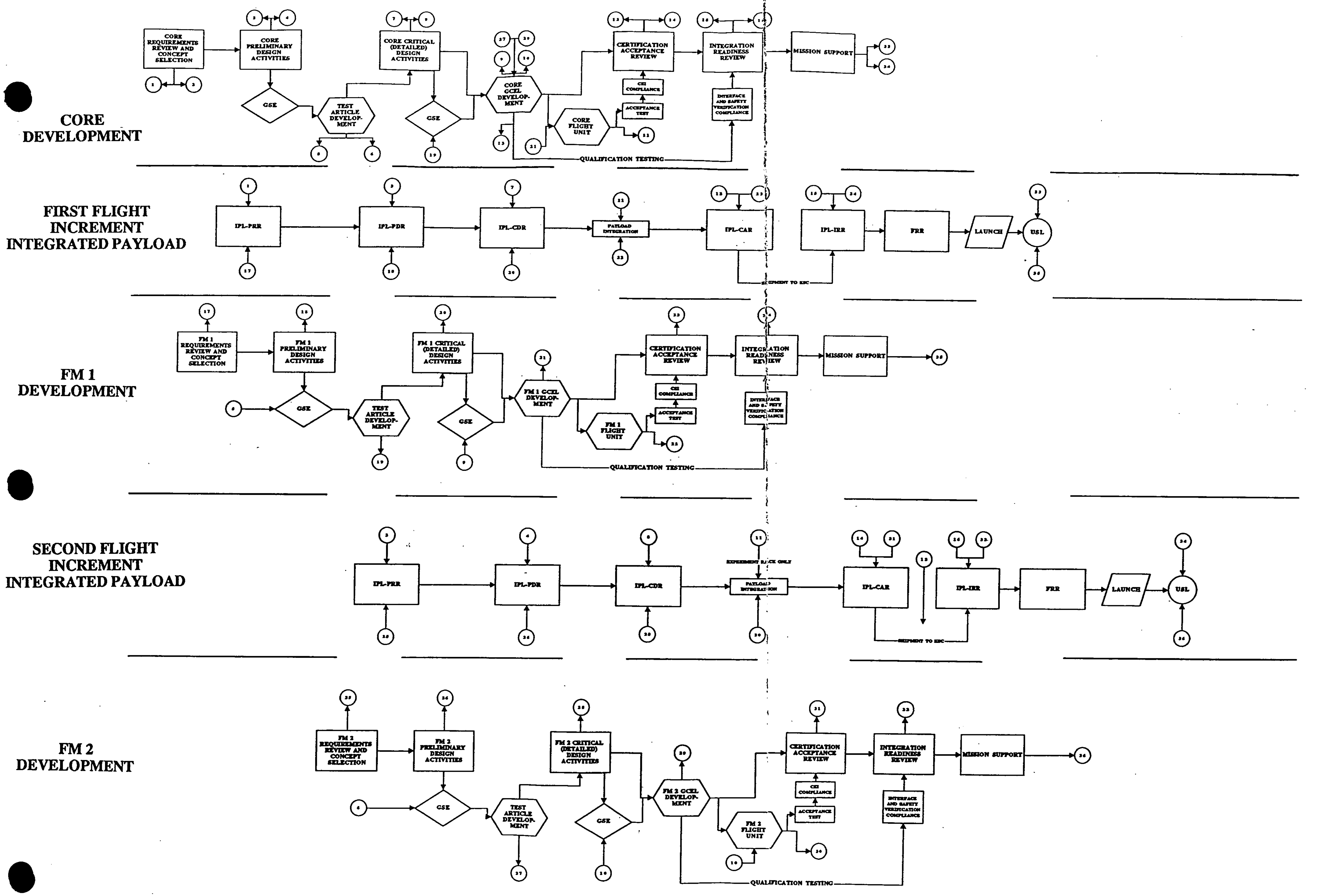
- The FM 2 and SSFF Core equipment (ER structure) will be delivered to KSC as a pre-integrated ER for the second flight increment.

- The integration of the FM 2 into the SSFF Core equipment (ER structure) will be performed at the SSFF MSFC Core developer's integration and checkout facility prior to delivery to KSC.

- The certification/verification of the FM 2 interfaces during ground integration and checkout activities at the SSFF MSFC Core developer's site and at KSC will be performed utilizing a SSFF Core Ground Control Experiment Laboratory (GCEL) of flight fidelity to accurately simulate the physical interface and the interface function the SSFF Core as it will be on-orbit in the USL.

- On-orbit verification of the integrated SSFF payload complements will be required to ensure the system safety and operation in the USL.

- The evolution of SSFF Core hardware and software will include the development of the following items:



FOLDOUT FRAME 1.

FIGURE 1.0-3 OVERALL SSFF TIME-PHASED LOGIC FLOW

FOLDOUT FRAME 2.

  - Test Article
  - GCEL
  - Flight Unit

- The evolution of the FM hardware and software will include the development of the following items:
  - Test Article
  - GCEL
  - Flight Unit

- Logistics management will allow the maximum usage of existing hardware and software, the design knowledge of hardware and software to be developed between the three separate contracts, and/or the actual hardware and software developed between the three contracts to prevent duplication of effort, which will provide cost savings.

- The SSFF Core Phase C/D contract Authority to Proceed (ATP) will initiate approximately six months prior to the ATP for the FM 1 Phase C/D contract.

- The ATP for the FM 2 Phase C/D contract will begin 18 months after the ATP for the FM 1 contract. This will maintain parallel development of each FM relative to their respective launch dates.

- The overall development time-phased logic flow for the SSFF based on the groundrules and assumptions listed previously, the WBS summary described in DR-5, and the Project Master Schedule included herein is depicted in Figure 1.0-3.

2.0 APPLICABLE DOCUMENTS

The following documents, latest revision unless otherwise specified, are a part of this specification to the extent specified herein. In the event of conflict between documents referenced herein and the contents of this specification, this specification shall apply.

SSP Documents

Document Number	Title
SSP 30219	Space Station Reference Coordinate System
SSP 30482	SSF Electrical Power Specification and Standard Vol. I EPS Electrical Verification Specification
SSP 30482	SSF Electrical Power Specification and Standard Vol II Consumer Restraints
SSP 41002	International Standard Payload Rack NASA/ESA/NASDA Modules Interface Control Document

MSFC Documents

Document Number	Title
JA-418	Payload Flight Equipment Requirements for Safety Critical Structures
MM 8040.12	Standard Contractor Configuration Management Requirements, MSFC Programs
MM 8075.1	MSFC Software Management and Development Requirements 91 Manual
MMI 1710.6	MSFC Program for Personnel Certification
MMI 5320.1	Implementation of the NASA Standards Parts Program
MMI 6400.2	Management Instruction-Packaging, Handling, and Moving Program Criteria Hardware
MSFC-HDBK-505	Structural Strength Program Requirements
MSFC-HDBK-527	Materials Selection List for Space Hardware Systems
MSFC-HDBK-668	Model Data Procurement Document for Spacelab Payload (Instrument or Facility) Phase C/D Contracts
MSFC-HDBK-1453	Fracture Control Program Requirements
MSFC-PROC-1301	Guidelines for Implementation of Materials Control Procedures
MSFC-SPEC-222	Resin Compounds, Electrical and Environment Insulation, Epoxy

MSFC-SPEC-250	Protective Finishes for Space Vehicles Structures and Associated Flight Equipment, General Specification for
MSFC-SPEC-266	Plates, Identification, Metal Foil, Adhesive Backed
MSFC-SPEC-494	NASA Installation of Wiring Assembly (Electrical Wiring), Space Vehicle, General Specification for
MSFC-SPEC-504	Welding, Aluminum Alloys
MSFC-SPEC-522	Design Criteria for Controlling Stress Corrosion Cracking
MSFC-SPEC-548	Vacuum Baking of Electrical Connectors
MSFC-SPEC-560	Specification, Welding, Steel, Corrosion and Heat Resistant Alloys
MSFC-SPEC-684	Vacuum Baking of Electrical Cables
MSFC-SPEC-708	Harness Identification Marker
MSFC-SPEC-1198	Screening Requirements for Non-Standard Electrical, Electronics, and Electromechanical Parts
MSFC-STD-156	Riveting, Fabrication and Inspection, Standard for
MSFC-STD-275A	Marking of Electrical Ground Support Equipment, Front Panels, and Rack Title Plates
MSFC-STD-349	Standard Electrical and Electronic Reference Designations
MSFC-STD-355	Radiographic Inspection of Electronic Parts
MSFC-STD-481	Radiographic Inspection Procedures and Acceptance Standards for Fusion Welded Joints in Stainless and Heat Resistant Steel
MSFC-STD-486	Threaded Fasteners, Torque Limits for
MSFC-STD-506	Materials and Processes Control
MSFC-STD-509	Lubricant Selection
MSFC-STD-512	Man/System Requirements for Weightless Environments
MSFC-STD-513	Personnel Certification for Packaging, Handling, and Moving of Program Critical Hardware
MSFC-STD-531	High Voltage Design Criteria
MSFC-STD-555A	MSFC Engineering Documentation Standard (Supersedes MSFC-STD-555)
MSFC-STD-561	Threaded Fasteners, Securing of Safety Critical Flight Hardware Structure Used on Shuttle Payloads and Experiments

MSFC-STD-655	Weld Filler Metal, Control of
MSFC-STD-781	Standard for Electrical Contacts, Retention Criteria
MSFC-STD-1249	Standard, NDE Guidelines and Requirements for Fracture Control Programs
S&E 5310.2	Equipment Logs/Records
SS-HDBK-0001	WP01 Elements Accommodation Handbook
SS-RQMT-0009	MSFC Space Station Documentation Preparation Requirements
SS-SPEC-0003	Logistics Elements Contract End Item Specification
SS-SRD-0001B	Space Station Freedom Program Definition and Requirements, System Requirements

JSC Documents

Document Number	Title
JSC-20793	Manned Space Vehicle Battery Safety Handbook
JSC 30200	Documentation Format Requirements
JSC-SC-M-0003	Functional Design Requirements for Manned Spacecraft and Related Flight Crew Equipment, Markings, Labeling, and Color
JSC-SE-R-0006	General Specification Requirements for Materials and Processes
JSC-SL-E-0002	Electromagnetic Interference Characteristics, Requirements for Equipment
JSC-SN-C-0005	NASA Specification Contamination Control Requirements for the Space Shuttle Program
JSC-SPEC-M1	Specification, Marking and Identification
JSC-SP-R-0022	General Specification Vacuum Stability Requirements of Polymeric Material for Spacecraft Application
NSTS 1700.7	Safety Policy Requirements for Payloads using the Space Transportation System
NSTS 13830	Implementation Procedures for STS Payloads System Safety Requirements

Other NASA Documents

Document Number	Title
CR 5320.9	Payload and Experiment Failure Mode and Effects Analysis and Critical Items List Groundrules (NASA)

FED-STD-209	Clean Room and Work Station Requirements, Controlled Environment
ICD-2-19001	Shuttle Orbiter/Cargo Standard Interfaces
KHB 1700.7	Space Transportation System Payload Ground Safety Handbook
NASA-RP-1024	Anthropometric Volume I
NASA-STD-3000	Volume IV: Space Station Man-Systems Integration Standards
NHB 5300.4 (1B)	Quality Program Provisions for Aeronautical and Space System Contractors
NHB 5300.4 (1D-2)	Safety, Reliability, Maintainability, and Quality Provisions for the Space Shuttle Program
NHB 5300.4 (3A-1)	Requirements for Soldered Electrical Connections
NHB 5300.4 (3G)	Requirements for Interconnecting Cables, Harnesses, and Wiring
NHB 5300.4 (3H)	Requirements for Crimping and Wire Wrap
NHB 5300.4 (3I)	Requirements For Printed Wiring Boards
NHB 5300.4 (3J)	Requirements for Conformal Coating and Staking of Printed Wiring Boards and Electronic Assemblies
NHB 5300.4 (3K)	Design Requirements for Rigid Printed Wiring Boards and Assemblies
NHB 6000.1	Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems, Equipment, and Associated Components
NHB 8060.1	Flammability, Odor, and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion
NHB 8071.1	Fracture Control Requirements for Payloads Using the National Space Transportation System

<u>Military Documents</u>

Document Number	Title
DOD-STD-100	Engineering Drawing Practices
MIL-B-5087	Bonding, Electrical, and Lightning Protection for Aerospace Systems
MIL-B-7883	Brazing of Steels, Copper Alloys, Nickel Alloys, Aluminum and Aluminum Alloys
MIL-C-17	Cables, Radio Frequency, Flexible and Semi-rigid, General Specification for

MIL-C-5015	Connectors, Electrical, Circular, Threaded, AN Type, General Specification for
MIL-C-5541	Chemical Conversion Coatings on Aluminum Alloys
MIL-C-27500	Cable, Electrical, Shielded and Unshielded, Aerospace
MIL-C-39012	Connectors, Coaxial, Radio Frequency, General Specifications for
MIL-E-6051	Title
MIL-E-45782	Electrical Wiring, Procedure for
MIL-HDBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures
MIL-HDBK-17	Plastics for Aerospace Vehicles
MIL-HDBK-23	Structural Sandwich Composites
MIL-HDBK-216	R.F. Transmission Lines and Fittings
MIL-P-27401	Propellant Pressurizing Agent, Nitrogen
MIL-P-55110	Printed Wiring Boards, General Specification for
MIL-S-7742	Screw Threads, Standard Optimum Selected Series, General Specification for
MIL-S-83519	Title
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification Marking of US Military Property
MIL-STD-453	Inspection, Radiographic
MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-461	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-462	Electromagnetic Interferences Characteristics, Measurement of
MIL-STD-750	Test Methods for Semiconductor Devices
MIL-STD-883	Test Methods and Procedures for Microelectronics
MIL-STD-889	Dissimilar Metals
MIL-STD-970	Standards and Specifications, Order of Preference for the Selection of

MIL-STD-975	NASA Standard Electrical, Electronic, and Electromechanical (EEE) Parts List
MIL-STD-981	Design, Manufacturing, and Quality Standards for Custom Electromagnetic Devices for Space Applications
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment & Facilities
MIL-STD-1686	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices)
MIL-T-31000	Military Specification, Technical Data Packages, General Specification for
MIL-T-43435	Military Specification, Tape, Lacing and Typing
MIL-W-6858	Welding, Resistance; Aluminum, Magnesium, Non-Hardening Steels or Alloys, Nickel Alloys, Heat Resisting Alloys, and Titanium Alloys; Spot and Seam
MIL-W-22759/3	Wire, Electric, Fluoropolymer-Insulated, TFE-Glass-TFE, Nickel-Coated Copper Conductor, 600-Volt
MIL-W-22759/12	Wire, Electric, Fluoropolymer-Insulated, Extruded TFE, Nickel-Coated Copper Conductor, 600-Volt
MIL-W-22759/23	Wire, Electric, Fluoropolymer-Insulated, Extruded TFE, Nickel-Coated High Strength Copper Alloy Conductor, 600-Volt
MIL-W-81381	Wire Electric Polymide-Insulated, Copper or Copper Alloy

Other Documents

Document Number	Title
320SPC0003	Critical Item Specification for Space Station Furnace Facility Rack Structures
D683-10577-1	Space Station Freedom Thermal Control System Coolant
JA55-032	Space Station Furnace Facility Capability Requirements Document
NAS 1746	Splice Shield Determination, Solder Style, Infrared Shrinkable, Insulated, Moisture Resistant
QQ-B-575	Braid, Wire, (Copper, Tin-Coated, or Silver Coated, Tubular or Flat)
QQ-R-566	Rod and Electrodes, Welding Aluminum and Aluminum Alloys
S683-29618	Prime Item Development Specification for Space Station Freedom United States Laboratory Vacuum System

3.0 NASA PROGRAM MANAGEMENT

The NASA Program Management activities required to accomplish the successful development of the SSFF and its major elements including the SSFF Core hardware and software, the FM 1 hardware and software, the FM 2 hardware and software, and their associated GSE and training equipment will include management direction and contracts administration functions. The management direction function will consist of monitoring the performance of each of the SSFF element developers with respect to their individual development schedules, as well as to the overall development schedule for each flight increment, providing final decision on the critical risk path that the development of each SSFF element and integrated payload for each flight increment will take, conducting performance assessments of each of the developers at each of the major milestones/reviews for each element, and providing management of the NASA engineering and test labs and the PIs activities with respect to the SSFF development, maintenance, and on-orbit operations. The contract administration will evaluate the financial performance of each of the contractors with respect to scheduled deliverables to NASA Program Management, will maintain the budget and available funding allocations throughout the program, and will provide interpretation of the contractual obligations of each party involved in the SSFF program.

3.1 CRITICAL PATH IDENTIFICATION

Monitoring the performance of each of the SSFF element developers with respect to their individual schedules as well as the overall development schedules for each flight increment will include evaluating the contractors' deliverables versus the contract and schedule to ensure that the contractors' are continuing on a least risk path with respect to schedule, cost, and technology.

The provision of critical path selection is a NASA Program Management activity to reduce the risks incorporated into any aerospace development with respect to schedule expediency, cost reductions, and technology advancements versus the use of existing technology, as well as logistics planning to reduce costs. This activity will involve the evaluation and analysis of the respective elements' course development versus budget and schedule constraints of the SSFF program.

3.2 PERFORMANCE EVALUATION

The performance evaluations for each element as applicable to the major milestones/reviews for each element will include the analyses of data deliverables from each element developer contractor for compliance with appropriate interface and specification documentation as deemed by the SSFF development contract, and the attendance and monitoring of the reviews and other meetings between each developer and between each developer and the Space Station Freedom Program (SSFP). This activity will include the assigning of action items and corresponding due dates to accomplish the long-term and short-term program objectives as applicable.

3.3 ENGINEERING AND TEST LAB DIRECTION

The NASA Program Management will also provide direction to the NASA engineering and test labs in support of the development of the SSFF elements independently, and for each flight increment identified. These activities will include coordination of the engineering and test labs attendance at reviews and meetings, responses to contractor questions, and timely response of discrepancies notification in product deliverables from the contractors.

3.4 CONTRACT ADMINISTRATION

The contract administration will perform the activities associated with budget availability and usage planning with respect to particular phases of the SSFF development. This will include the interpretation and determination of change of scope activities as deviates from the original development plan, the financial performance monitoring of each element at each major milestone/review.

4.0 NASA ENGINEERING & TEST LABS

The NASA Engineering and Test Labs activities required to accomplish the successful development of the SSFF and its associated support equipment, and perform and maintain successful operation in the USL will include support from the Chief Engineer's Office (CEO), Science and Engineering (S&E) Labs, and the Test Labs for each SSFF element as applicable to the integrated payloads for each flight increment.

4.1 CHIEF ENGINEER'S OFFICE (CEO)

The CEO will coordinate the overall review of each element's project development including the coordination of the NASA S&E and Test Labs to support the major milestone/review activities of the element developers. Interfacing with the developers through scheduled meetings, telecons, and routine communication to receive questions on or identify areas of the design approach that requires interpretation for acceptability by appropriate S&E and Test Labs personnel, before continuing with the design, is an activity that the CEO will perform. The CEO will also coordinate the review of all design material submitted by the developers prior to major milestones/reviews for review by the NASA S&E disciplines for integration and verification compliance as required at each phase of the development process for each element and the integrated payloads for each flight increment. The CEO will also coordinate the review of any changes to design, integration or verification documentation, and maintain the schedule for documentation submittal and acceptance.

4.2 SCIENCE & ENGINEERING LABS

The S&E Labs will support the analytical integration of design inputs from each of the SSFF elements' developers as driven by the major milestones/reviews inputs requirements identified in the IROP. The activities to be performed by the S&E disciplines will include reviewing all design inputs from the element developers and providing discrepancy notice comments as applicable, providing interpretation of design specification requirements as identified in the NASA program documentation defining all NASA interfaces and operating procedures, and providing definition of interface and safety verification to the developers as applicable to each element.

4.3 TEST LABS

The Test Labs will support the testing requirements of each element developer as applicable to their respective designs as driven by major/milestones reviews. These activities will include the review of design inputs and associated test plans (structural, dynamic, materials certification, toxic offgassing, EMI, etc.) from element developers, providing comments to the test plans including necessary changes for test compliance with respect to verification acceptability, planning activities to schedule element developer tests in coordination with the SSFF integration schedules and the schedules of other programs in operation at NASA, and the performance of testing activities including EMI testing, materials testing for toxicity, flammability, and structural corrosion reactions under expected orbital environments, toxic offgas testing of all element components, structural testing, and dynamic (vibration) testing.

5.0 DESIGN, DEVELOPMENT, TEST, & ENGINEERING (DDT&E)

The activities required to perform the evolutionary development of the Space Station Furnace Facility (SSFF) hardware and software will be discussed in this section. The plan to develop the SSFF will initially require the development of Test Article and Ground Control Experiment Laboratory (GCEL) hardware and support software for each of the major SSFF elements including the Core, FM 1, and FM 2. The evolutionary development of each element of the SSFF will ensure the successful development of Flight Unit hardware and software, which will minimize on-orbit integration and verification risks, as well as maximize the hardware, software, and operational reliability. The typical activities involved in the design, development and testing of each set of hardware and software includes concept identification, concept selection, performance of design analyses, preparation of analyses documentation, identification and design of support equipment (ground support and test support), fabrication and/or procurement of components for assembly, test of components or subassemblies for use environments, and system integration and checkout. All design activities will ultimately support the design, development, and delivery of the Flight Unit hardware and software for the SSFF. The Test Article and GCEL equipment and supporting software and equipment development efforts for each of the major elements of the SSFF will be detailed within this section of the PIP.

5.1 DESIGN MAJOR MILESTONE/REVIEW SUMMARY

The design, development, test, and engineering activities for the SSFF will be conducted and assessed for progress and compliance with program requirements during the typical phases (major milestones/reviews) of the element design process. These major milestones/reviews for each element will include the Preliminary Requirements Review (PRR), the Preliminary Design Review (PDR), the Critical Design Review (CDR), the Certification/Acceptance Review (CAR), and the Integration Readiness Review (IRR). The participation in integrated payload (IPL) reviews for each IPL complement for each flight increment will also be conducted to assess progress and compliance with the mission integration process. The major milestones/reviews associated with the mission integration process will include IPL-PRR, IPL-PDR, IPL-CDR, IPL-CAR, and IPL-IRR. The phased safety reviews (i.e., 0/I, II, and III) for the NSTS and the USL are required for the individual payload designs and the IPL complement for each flight increment, and the Flight Readiness Review (FRR) will apply to IPL complements. A description of the

requirements and activities required between each of the major milestones/reviews from Authority to Proceed (ATP) of the Phase C/D contract are presented in the following paragraphs.

The PRR and the IPL-PRR are the reviews in which element requirements will be baselined for the individual elements and as an integrated payload, respectively. Between the Authority to Proceed (ATP) on the Phase C/D and the PRR, preliminary functional analyses will be performed to determine the allocations requirements with respect to SSF resources and operational aspects of the payload, and to identify and document the interfaces between the SSFF Core equipment and the SSF resources and the FMs. System concepts to satisfy the CEI Specifications and interface requirements will be identified, and the selection of the best system approach for continuing with the preliminary design will be identified prior to starting the next design phase. In particular, the identification of the interface design between each element will be required to allow each element developer to initiate preliminary concept identification and system selection. The period between design PRR and IPL-PRR will allow for updates to the design PRR inputs as required per Review Item Discrepancies (RIDs).

The PDR is the review in which the element developers will prove the technical acceptability of their selected design approaches. The activities that take place between the PRR and the PDR for each element include the performance of analytical design, the production of supporting documentation and drawings to demonstrate the design physical and functional interface compatibility and resource allocations usage between the SSF and the major SSFF elements, and incorporate IPL-PRR RIDs into the design input. These interfaces will include both hardware and software interfaces. Also, the interface and resource usage compatibility will be demonstrated by the initiation of Test Article hardware and software development, and the development of Ground Support Equipment (GSE). Resource interface design, resource distribution philosophy, and resource availability for the FMs will be upgraded from the concept selection for input to the FM developers during this phase to allow them the opportunity to upgrade their interface design and usage capabilities as required. This Test Article development will be complete and the checkout activities performed between PDR and CDR. The purpose of the Test Article hardware and software is briefly described in this section of the PIP, and in Section 9.0, Logistics. The Phase 0/I Safety Data Packages and subsequent reviews are developed and conducted, respectively, during this time period. The time period between design PDR and IPL-PDR will allow for updates of the design based on design PDR RIDs.

The CDR is the review in which the SSFF element developers will finalize their respective designs. The activities that take place between the PDR and the CDR include the

updating of analytical analyses and supporting documentation and drawings described in the previous paragraph to a sufficient detail to allow each developer to proceed with fabrication and assembly, and continue the planning for physical integration, training and simulation activities, and flight operations, and the incorporation of RIDs from the IPL-PDR into the design inputs. The development of Ground Control Experiment Laboratories (GCELs) to be used as qualification units for each element will be initiated during this time period, and will be completed and checkout activities performed between CDR and IRR for each of the respective SSFF major elements. The purpose of the GCEL will be briefly described in this section of the PIP and in Section 9.0, Logistics. The time period between the CDR and IPL-CDR will allow the finalization of the functional design RIDs, and following IPL-CDR, the finalization of interface design.

The CAR and the IRR are the reviews in which the major elements of the SSFF as-built hardware and software are accepted by the manager of the SSFF development contract and the integration organization (SSFP), respectively. These reviews will be conducted concurrently prior to integration of all SSFF articles and the integration of the SSFF into the logistics module, respectively. The activities that take place between the CDR and the CAR for each of the SSFF major elements include the actual fabrication of hardware and the final development and application of software, the assembly and integration of the SSFF elements' equipment, analytical and physical verification of the as-built configuration of the SSFF element equipment as reflected in the design documentation, compliance with the CEI Specifications, and the final functional acceptance testing of the as-built hardware and software for each of the SSFF Major elements. The activities requirements for the IRR are similar to those for the CAR. The development and review of safety and interface verification analyses reports (analytical and physical) as identified in the Verification Plan for the individual elements of the as-built SSFF equipment will be required. The applicability of these verification closeouts to the integrated SSFF will be assessed by the SSFP prior to turnover to KSC for integration into the logistics module. The Phase II Safety Data Package and subsequent review will be prepared and conducted, respectively, during the CDR-to-CAR phase of the integration process, and the plan for verifying each of the SSFF elements and through certification and acceptance will be finalized at this time (i.e., baselining of the Verification Plan for each element). The activities required for the IPL-CAR and IPL-IRR on the integrated payload for each flight increment will be similar to the individual payload design described above.

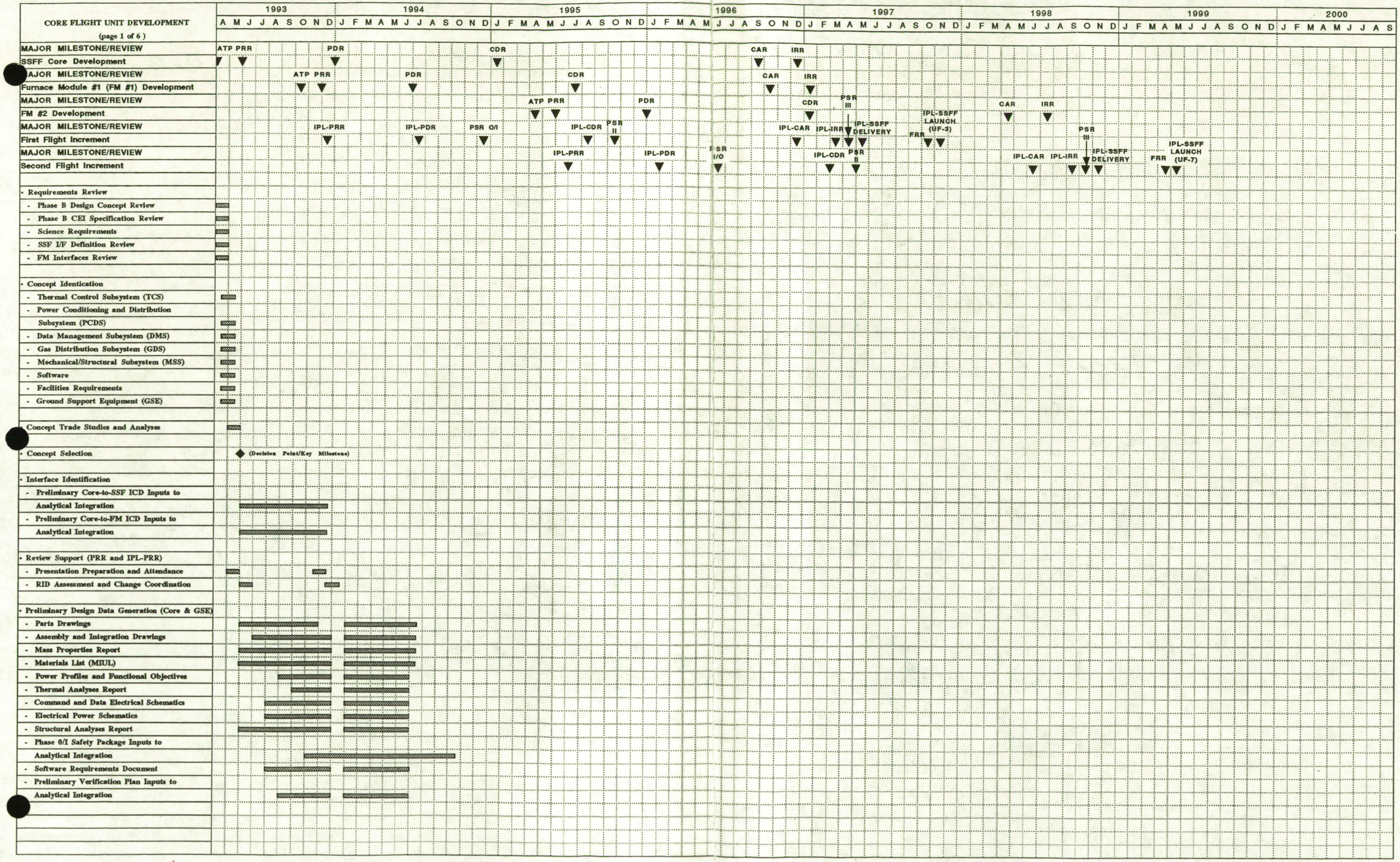
The FRR is the review at which each of the SSFF element developers will address the closure actions for any open work identified previously during the CAR and/or IRR. The Phase III Safety Data Package and subsequent review is required during the time

period between IRR and FRR. The activities performed between the CAR/IRR and the FRR will include those activities related to the physical integration and checkout activities at the SSFF Core developer site and at KSC prior to and during integration. These activities are detailed in section 6.2, Physical Integration.

The activities to develop each of the major elements of the SSFF including the Core, the FM 1, and the FM 2 equipment, require the same general task functions. The Core development will be the most complicated as it will be required to interface with the FM elements and the USL. The Core development activities will be used as the basis for describing the SSFF with respect to the overall evolutionary DDT&E functions for each element including the Flight Unit development, the Test Article development, and the GCEL development. The activity descriptions for the respective elements are presented in the following paragraphs.

5.2 FLIGHT UNIT DEVELOPMENT

The DDT&E task function activities identification and descriptions for associated Flight Unit hardware and software development descriptions required from ATP to hardware delivery will be detailed in the following paragraphs. Project development schedules depicting the Flight Unit development for the Core, the FM 1 and the FM 2 are included in Figure 5.2-1, Figure 5.2-2, and Figure 5.2-3, respectively. These schedules depict the time-phased logic of a typical DDT&E critical path identification including key milestones, decision points, interrelationships with other program elements, evolutionary hardware and software set deliveries, facilities requirements identification, and major reviews. Figure 5.2-1, the Core Flight Unit Project Development Schedule, depicts the subsystem-level flight and ground equipment developments, and provides typical detail for the DDT&E activities for each SSFF element. Figure 5.2-2 and Figure 5.2-3 provide a top-level identification of activities requirements with reference to Figure 5.2-1 for detail.



FOLDOUT FRAME 1.

FIGURE 5.2-1 CORE FLIGHT UNIT PROJECT DEVELOPMENT SCHEDULE
(page 1 of 6)

FOLDOUT FRAME 2.

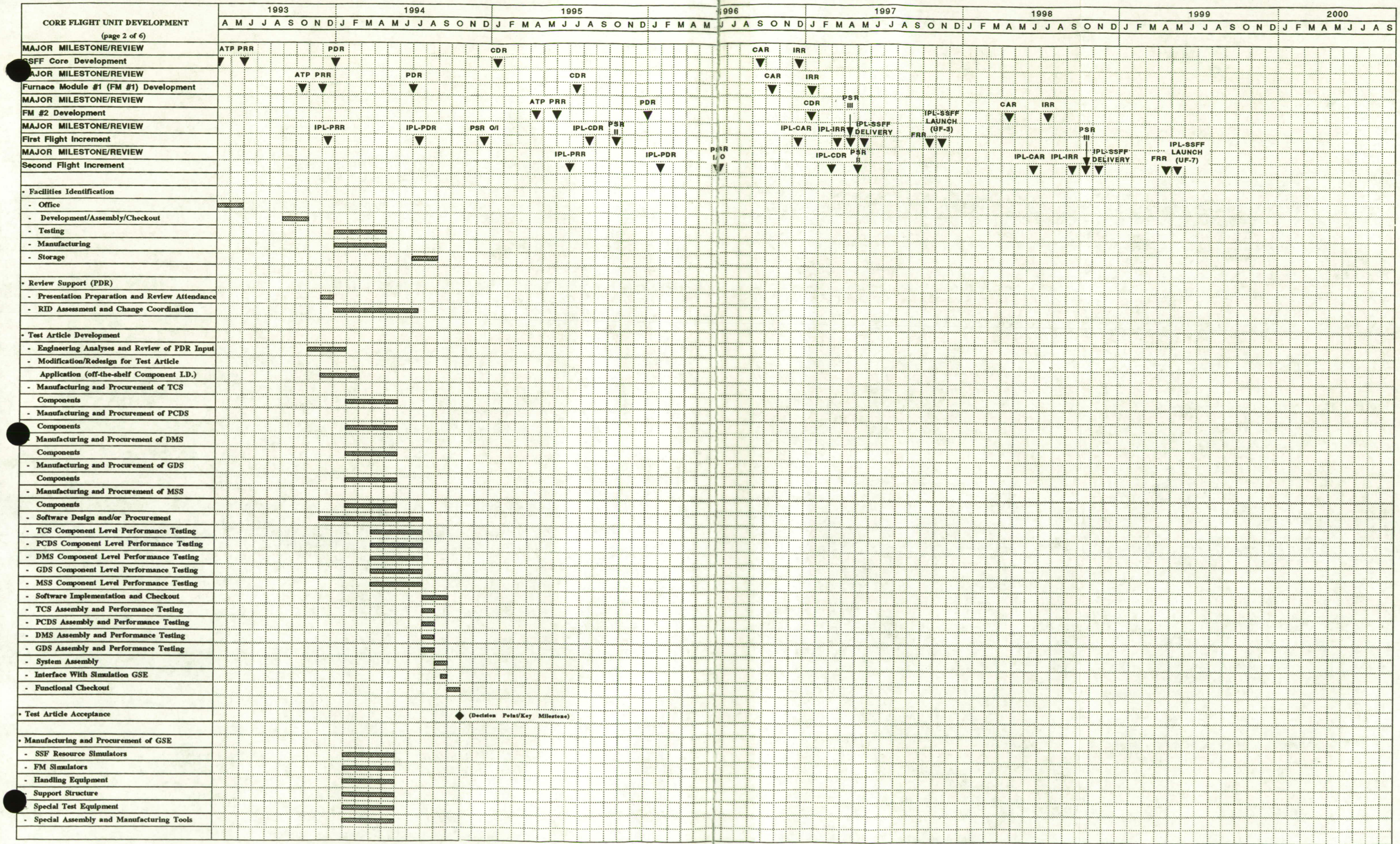


FIGURE 5.2-1 CORE FLIGHT UNIT PROJECT DEVELOPMENT SCHEDULE
(page 2 of 6)

FOLDOUT FRAME 1

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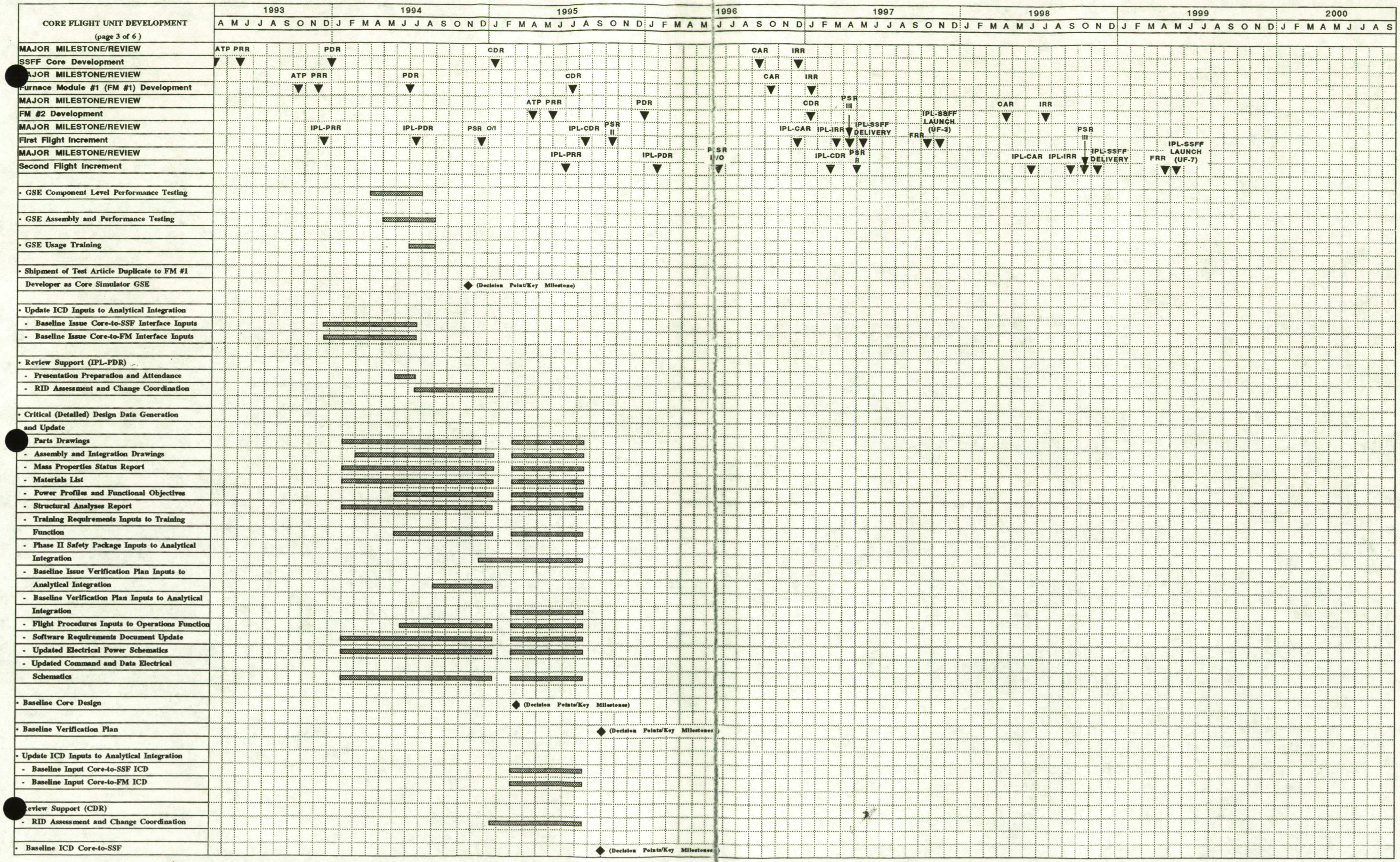

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FIGURE 5.2-1 CORE FLIGHT UNIT PROJECT DEVELOPMENT SCHEDULE
(page 3 of 6)

FOLDOUT FRAME 2

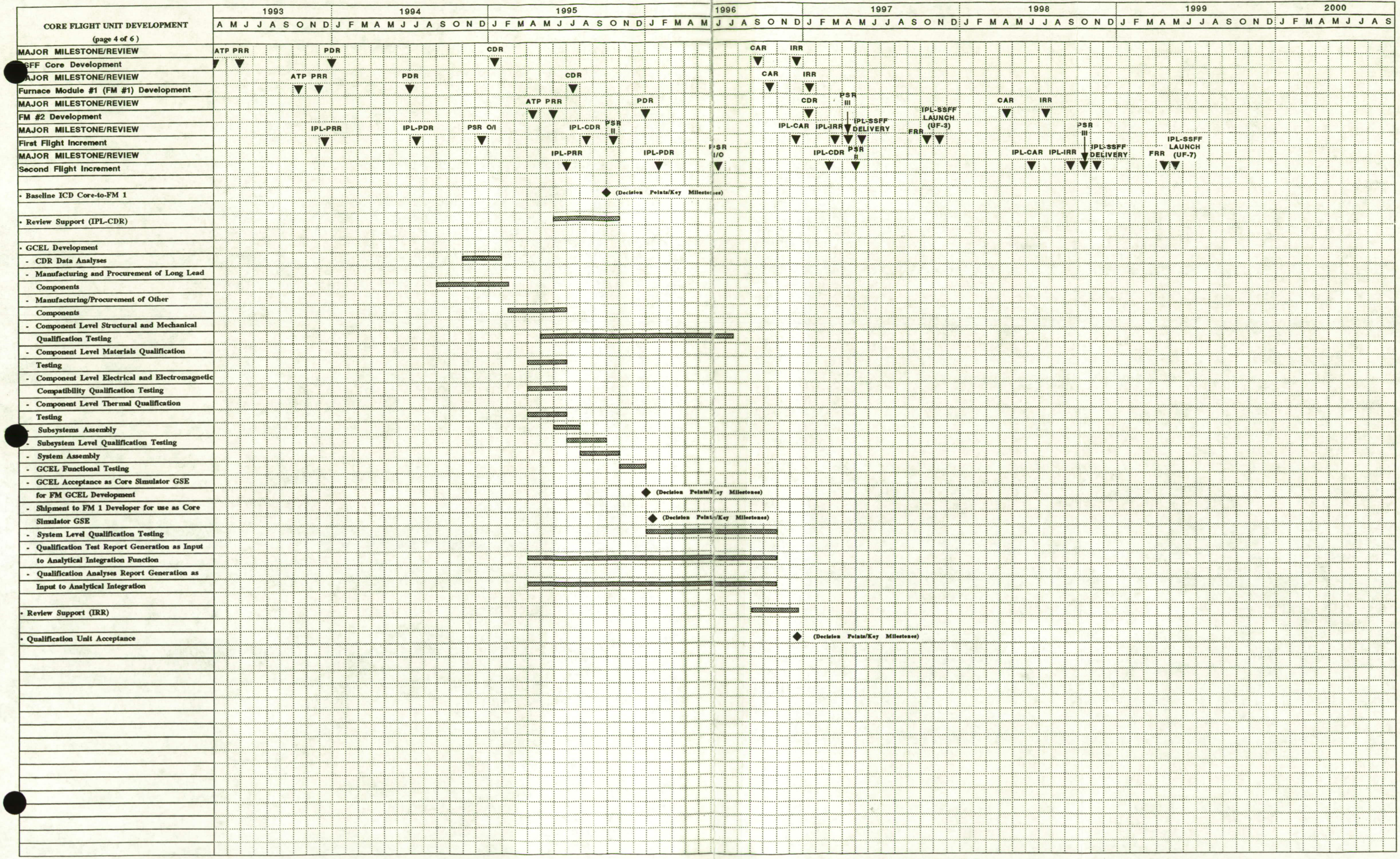

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FIGURE 5.2-1 CORE FLIGHT UNIT PROJECT DEVELOPMENT SCHEDULE
(page 4 of 6)

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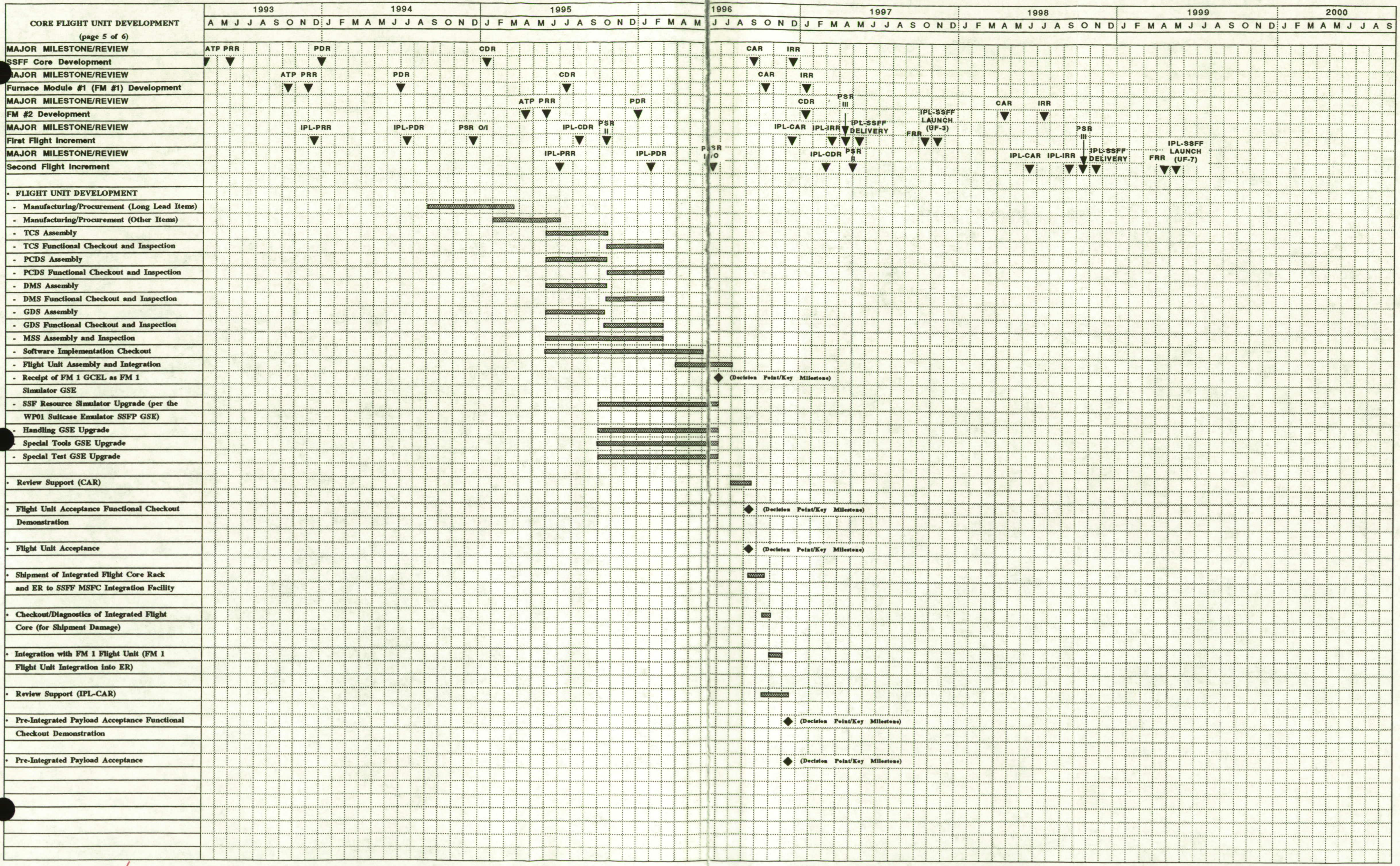

FOLDOUT FRAME 1.

FIGURE 5.2-1 CORE FLIGHT UNIT PROJECT DEVELOPMENT SCHEDULE
(page 5 of 6)

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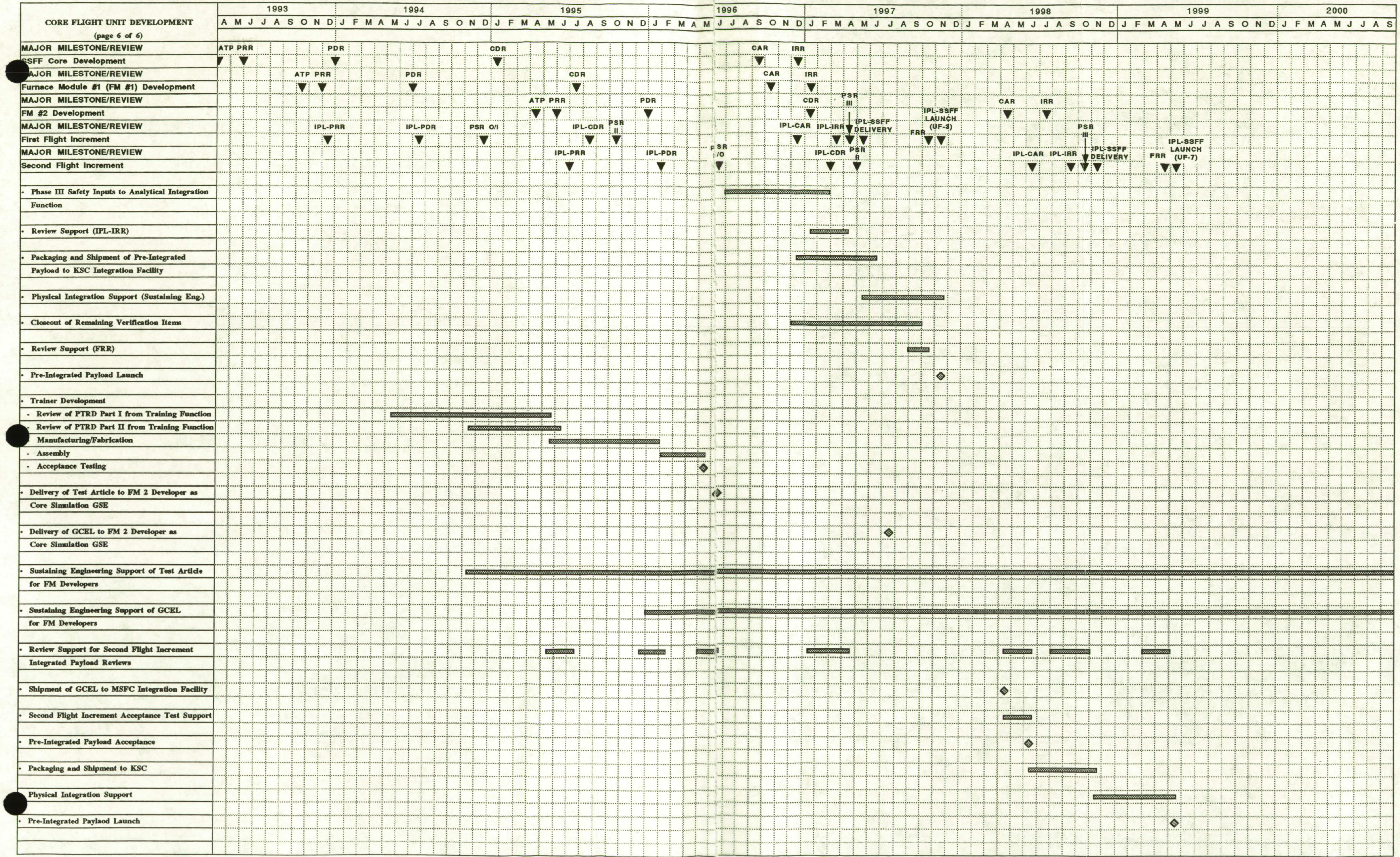

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FIGURE 5.2-1 CORE FLIGHT UNIT PROJECT DEVELOPMENT SCHEDULE
(page 6 of 6)

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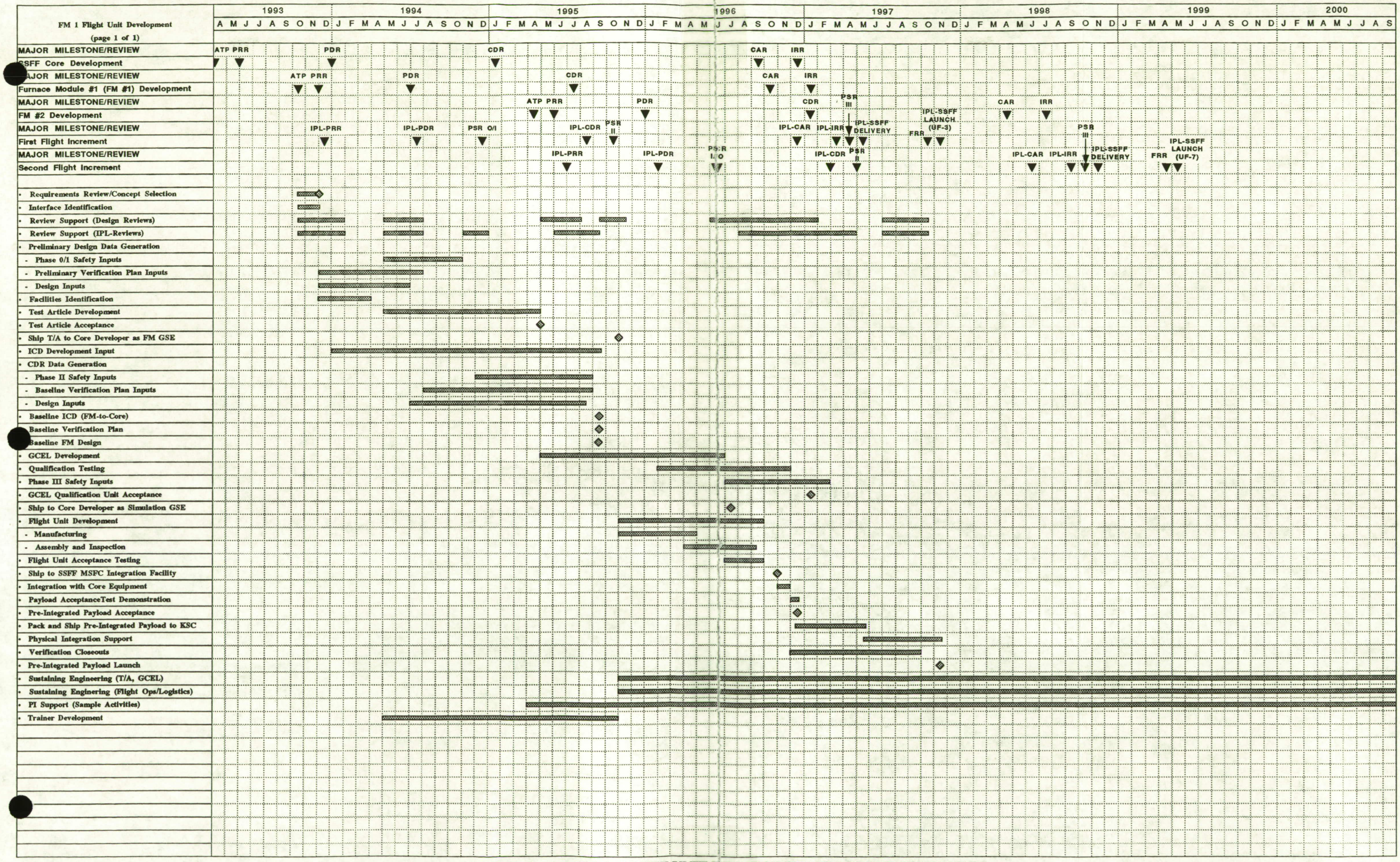

FIGURE 5.2-2 FM 1 FLIGHT UNIT PROJECT DEVELOPMENT SCHEDULE
(page 1 of 1)

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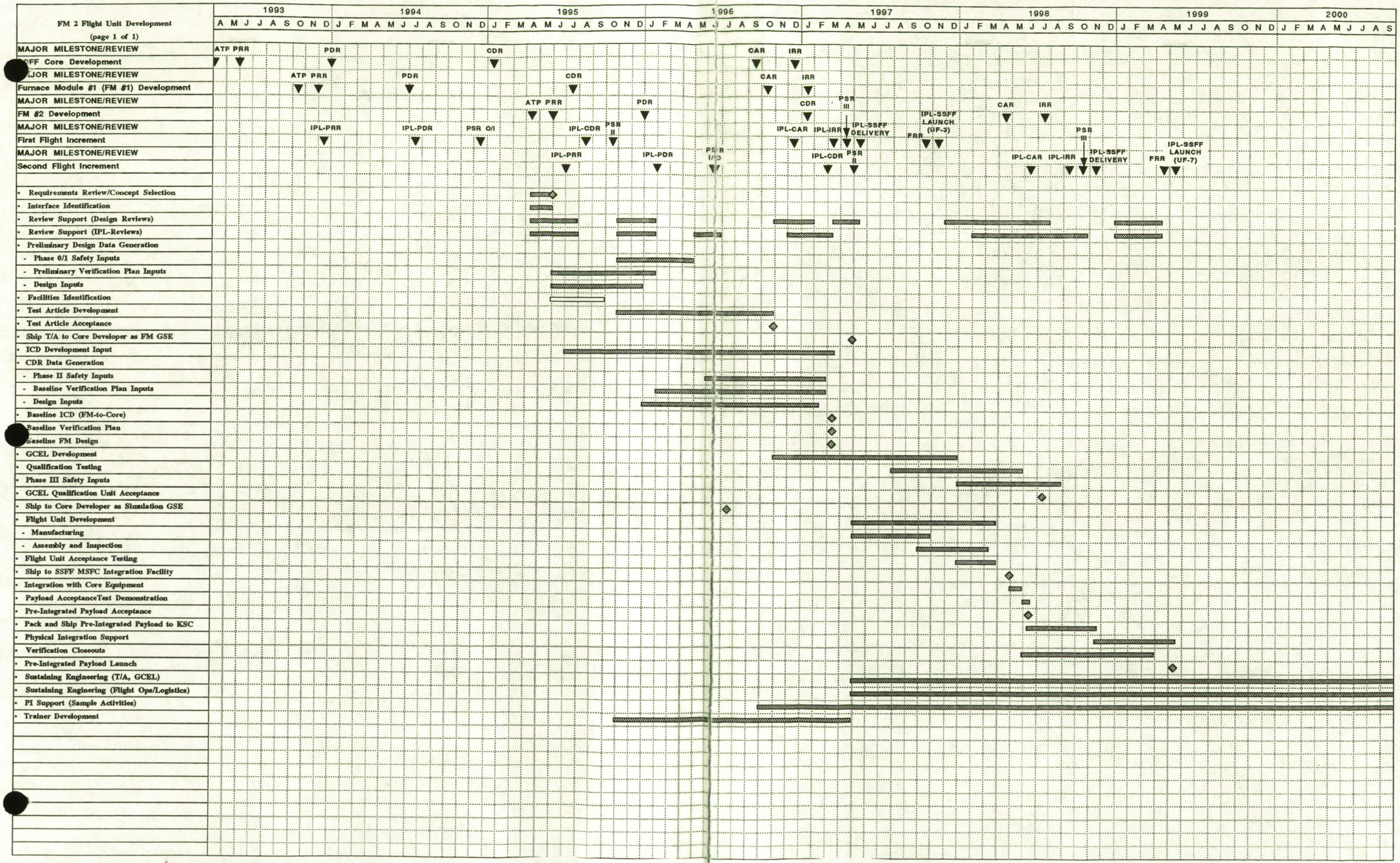

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FIGURE 5.2-3 FM 2 FLIGHT UNIT PROJECT DEVELOPMENT SCHEDULE
(page 1 of 1)

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5.2.1 Requirements Review

The DDT&E tasks required for the successful production of the SSFF Core hardware and software will begin with the review of the SSFF Core system concepts developed during SSFF contract, NAS8-38077 (Phase B). The systems concept identification phase of this effort will require a detailed understanding of the science requirements to assess the immediate and long term functional capabilities of the SSFF Core, and will require an accurate assessment of SSF resource utilization for the given science requirements, as well as for interface design and functional constraint identification. This effort will consist of not only the review of previous work, but also the latest design requirements and definitions from appropriate documents listed in Section 2.0, Applicable Documents.

The documentation developed and/or utilized during the SSFF Phase B study, that will be utilized most frequently during the requirements review and concept identification portion of the Phase C/D SSFF design will include the Science Capabilities and Requirements Document (SCRD), the Payload Accommodations Handbook Volume 1: Manned Base, the SSFF Contract End Item (CEI) Specification Document, the Integrated Requirements on Payloads (IROP), the Experiment/Facility Requirements Document (E/FRD), the Summary of Technical Reports for the SSFF Core, and the Flight and Ground Safety Policy and Requirements Documents. The science requirements compilation for the SSFF Core is located in the Science Capabilities and Requirements Document (SCRD), JA55-XXX, and defines the necessary capabilities requirements of the Furnace Modules (FMs), and subsequently, the SSFF Core. The SSF Payload Accommodations Handbook (SS-HDBK-0001) and reference text materials define the SSF resource interfaces (both physical and functional). The science requirements will govern the allocated SSF resources utilization, and will influence how these resources can be distributed and controlled by the SSFF Core for use by the FMs. The CEI Specification for the SSFF (320SPC0003) lists the performance requirements that the SSFF Core will be designed to meet at the Core Certification/Acceptance Review (CAR). The IROP document (SS-HDBK-0002) defines the documentation requirements to present the chosen design and show that it meets the applicable specifications requirements. The E/FRD document identifies the integrated resource requirements of the Core with respect to all areas of design and operation. The Summary of Technical Reports for the SSFF Core (320RPT0008) describes the subsystem level conceptual designs including components lists and interfaces to the FMs and the SSF resources for each subsystem in the SSFF Core. The Flight and

Ground Safety Policy Documents (NSTS 1700.7B and KHB 1700.7 A, respectively) define the safety constraints that all Core equipment and support equipment will take into account during their respective development phases.

The SSFF Phase B work included the identification of subsystem level concepts to provide the distribution and control of the SSF resources based on the strawman of two FMs, the Crystal Growth Facility (CGF) and the Programmable Multi-Zone Furnace (PMZF), in the United States Laboratory (USL) Module. These two furnaces enveloped most of the requirements in the SCRD, and provided a source of mature design data for the Phase B feasibility assessments. Figures 5.2.1-1 through 5.2.1-5 depict the functional interface block diagrams developed during the Phase B SSFF effort including Thermal Control interfaces, Electrical Power interfaces, Data Management interfaces, Gas Distribution interfaces, and Software interaction/interfaces, respectively. A review of these functional interface block diagrams will provide a preliminary concept and present a functional understanding of the Core interfaces to be designed.

5.2.2 Concept Identification

The SSFF Core subsystems concepts will be identified including all the physical and functional interfaces during this effort. SSFF Core subsystem preliminary detailed interface schematics will be developed as a product output for each of the chosen subsystem concepts as a result of the review effort described in section 5.2.1. Design management direction will be required as an input to this activity to maintain the subsystem concept selection within the program resources and goals. These schematics will be used for reference in the next phase of the SSFF Core development, which is the evaluation and determination of the selected concepts for continuation with the design process.

The SSFF Core subsystem concepts identified during the Phase B effort on the SSFF included the following:

- Mechanical/Structural Subsystem (MSS)
- Thermal Control Subsystem (TCS)
- Power Conditioning and Distribution Subsystem (PCDS)
- Data Management Subsystem (DMS)
- Gas Distribution Subsystem (GDS)

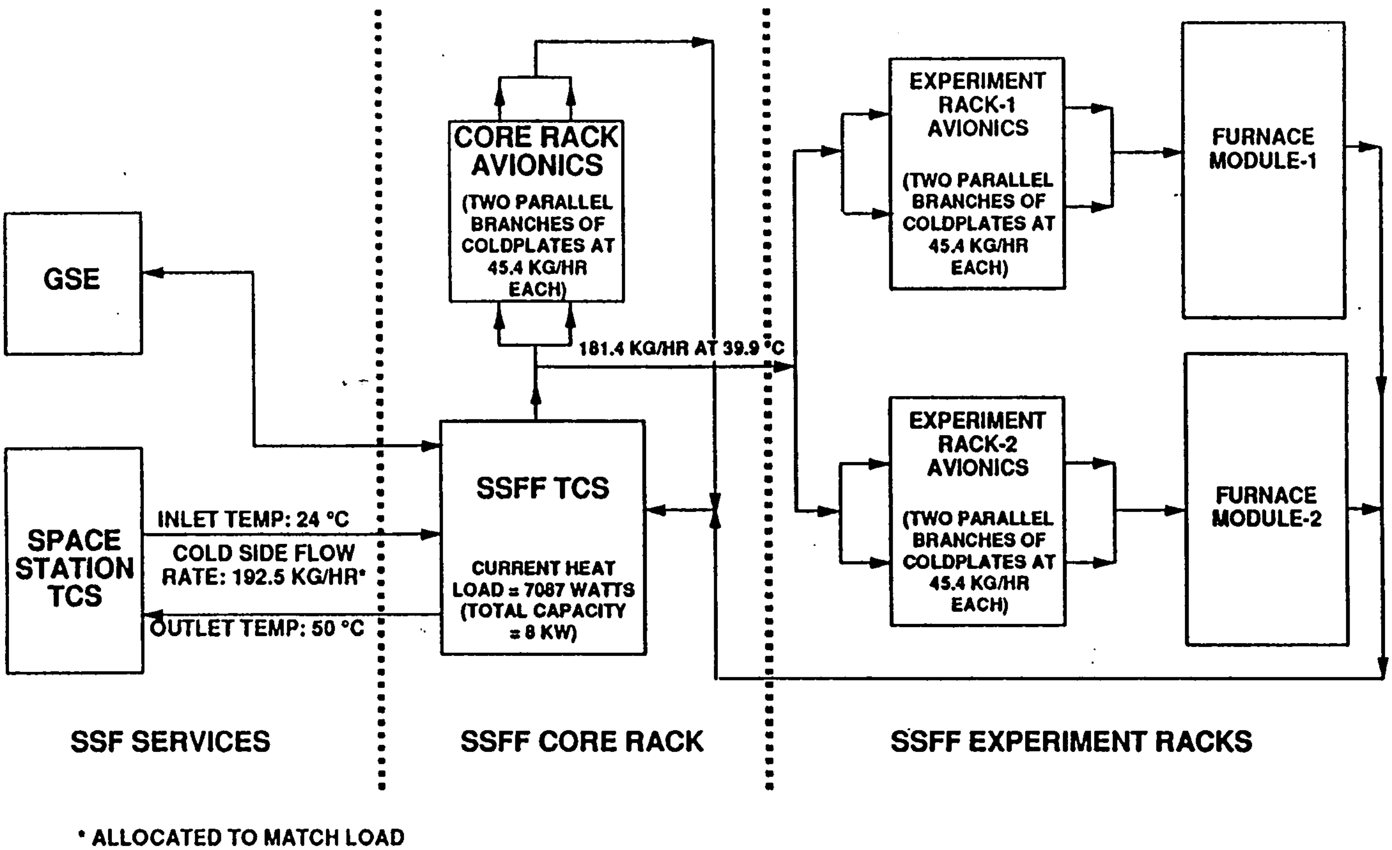


FIGURE 5.2.1-1 THERMAL CONTROL SUBSYSTEM (TCS) FUNCTIONAL BLOCK DIAGRAM

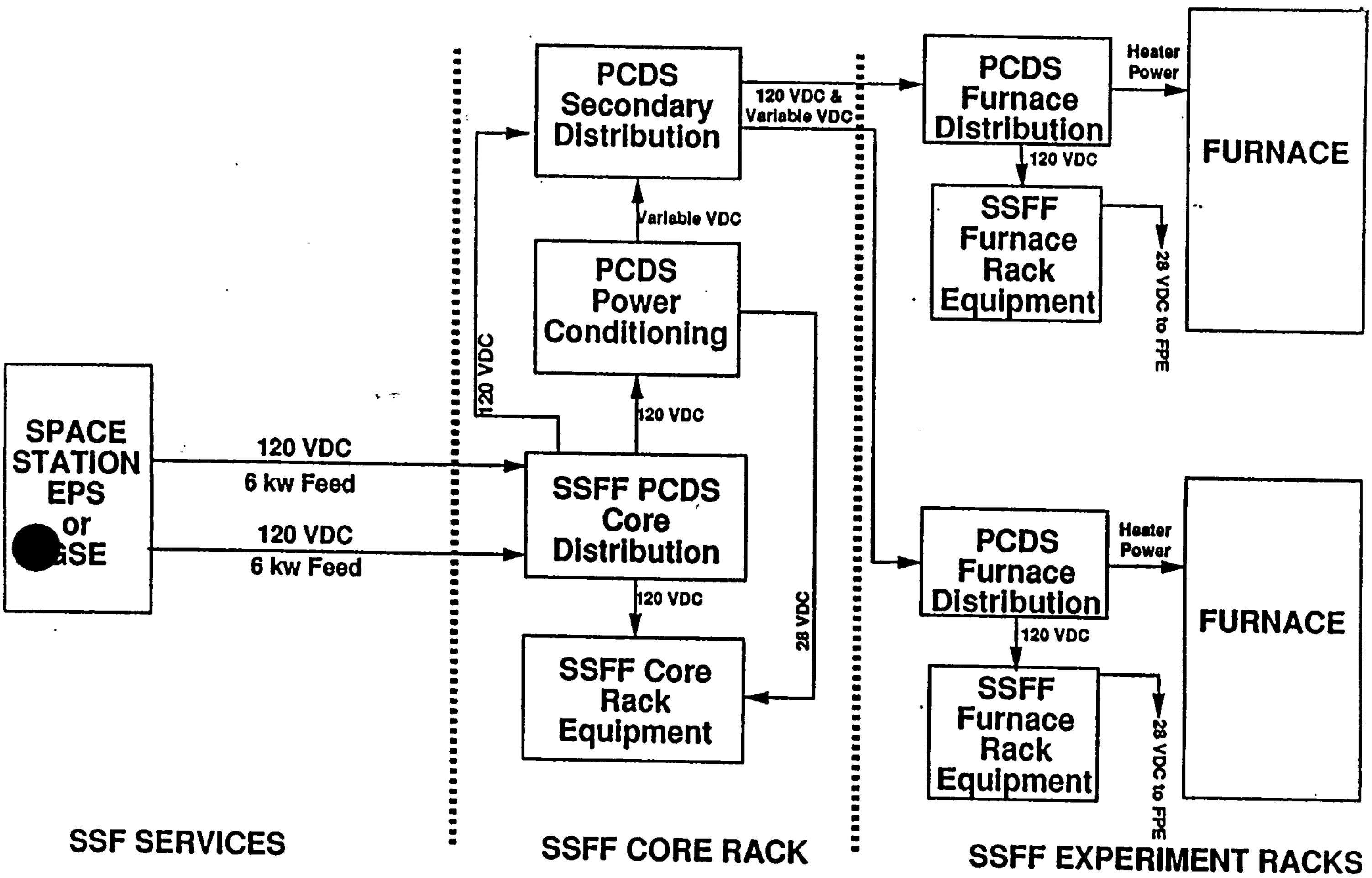


FIGURE 5.2.1-2 POWER CONDITIONING AND DISTRIBUTION (PCDS) FUNCTIONAL BLOCK DIAGRAM

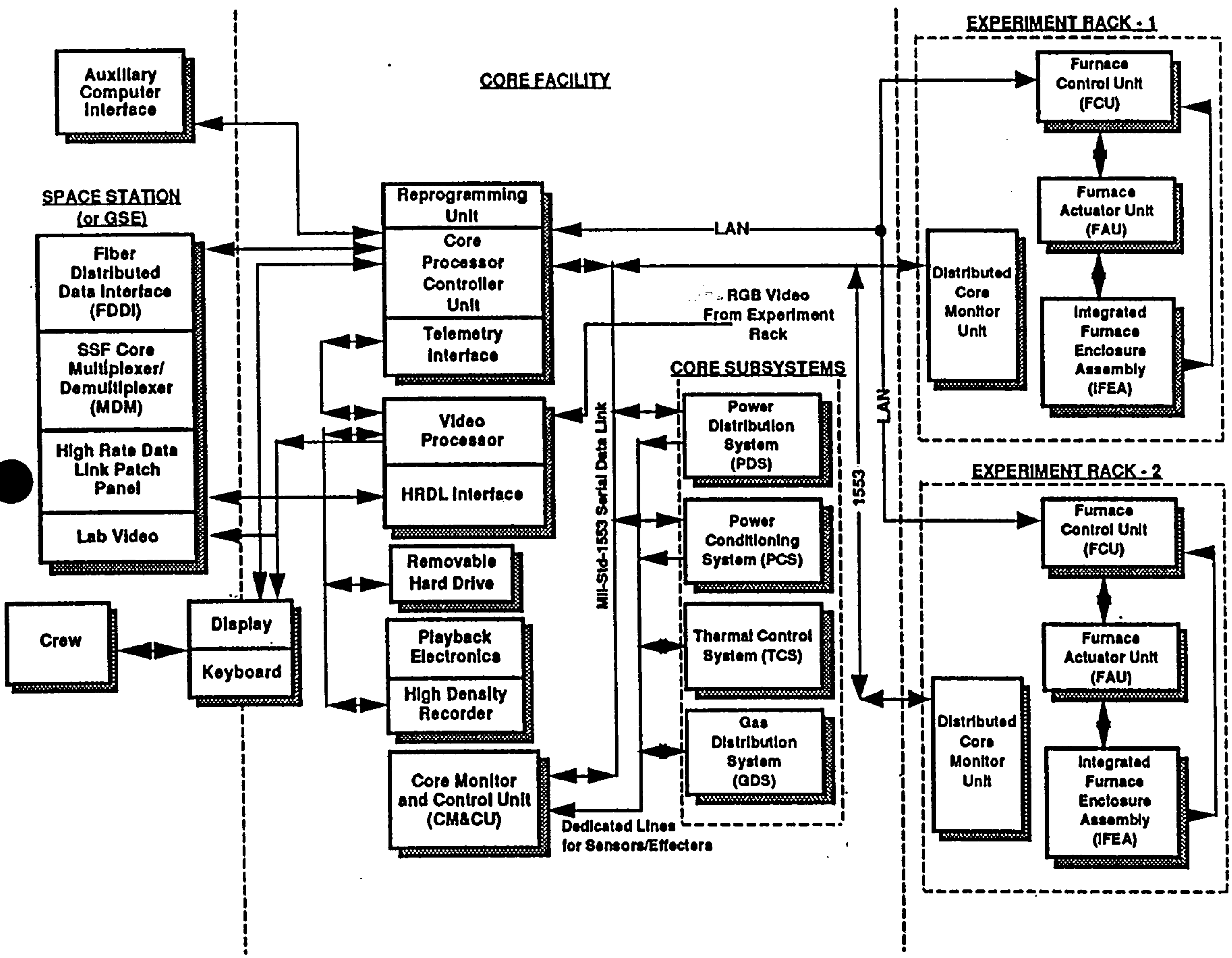


FIGURE 5.2.1-3 DATA MANAGEMENT SUBSYSTEM (DMS) FUNCTIONAL BLOCK DIAGRAM

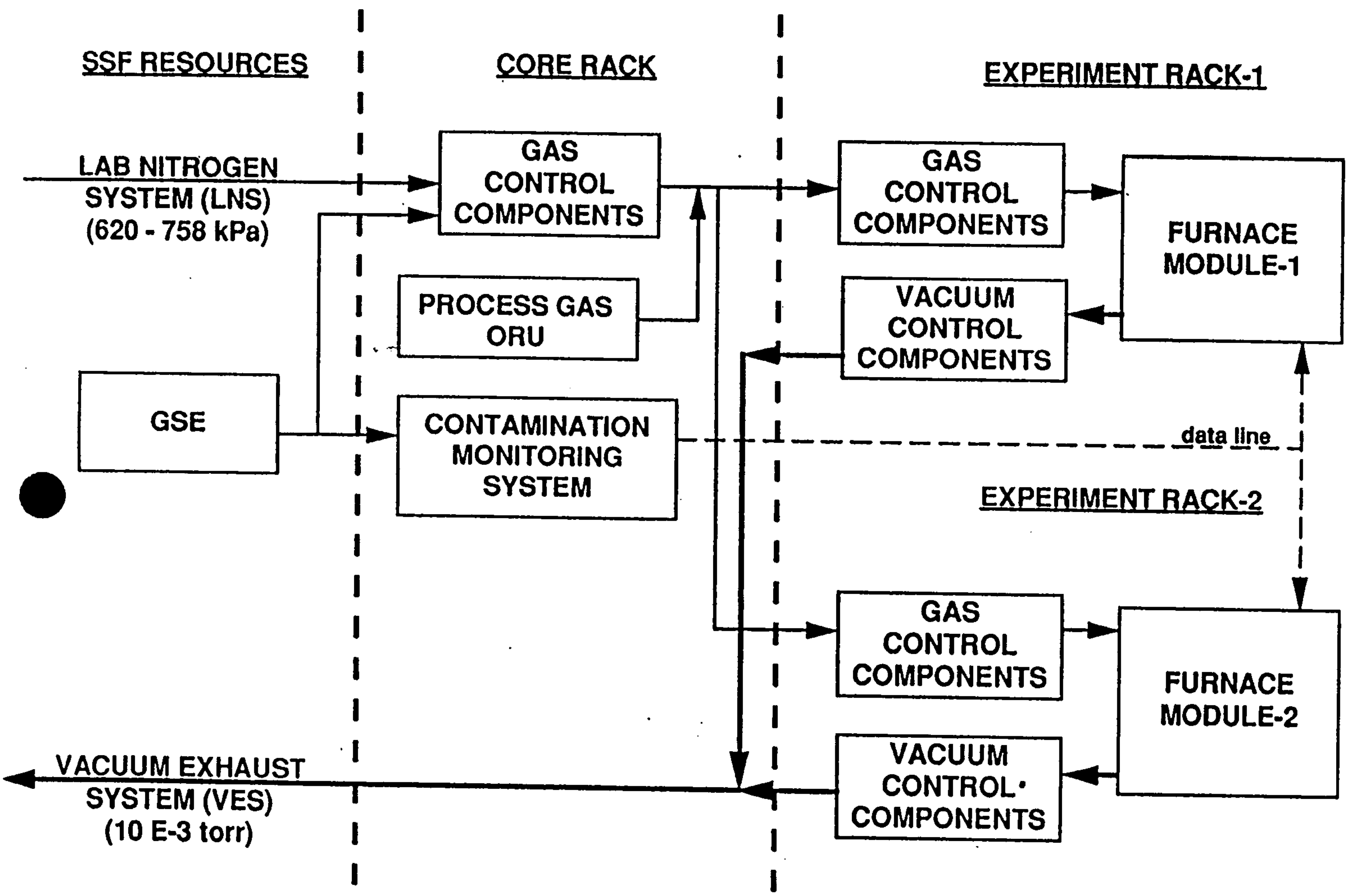


FIGURE 5.2.1-4 GAS DISTRIBUTION SUBSYSTEM (GDS) FUNCTIONAL BLOCK DIAGRAM

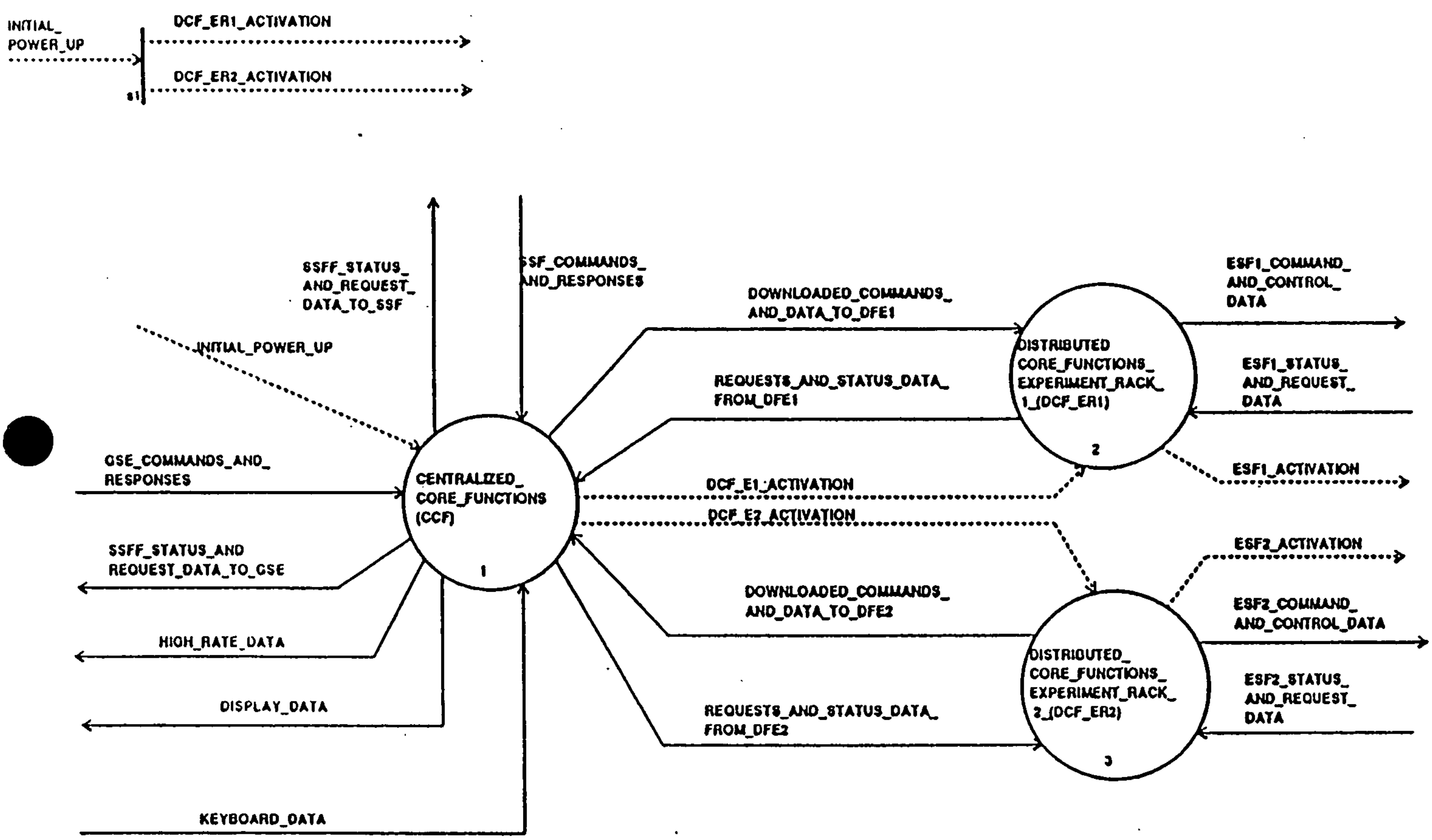


FIGURE 5.2.1-5 SOFTWARE FUNCTIONAL BLOCK DIAGRAM

The primary function of the MSS is to provide structural support for the FMs, the other SSFF Core subsystem structures, and to provide a practical rack layout for crew interface with respect to on-orbit operations, maintenance, and unit replacement.

The primary function of the TCS is to provide dissipation of heat generated by the FM rack (ER) equipment, and the Core rack electronics, and transfer this heat to the SSF Thermal Control System.

The primary function of the PCDS is to provide and distribute power to the various FM systems/subsystems, and to the Core Facility subsystems via interface with the SSF Experiment Power System.

The primary function of the DMS is to provide control, monitoring, and data management capabilities to the SSFF Core subsystems and the FM facilities, including interface to the SSF Data Management interfaces. The control, monitoring, and data management will be implemented via software developed as an integral part of the DMS.

The primary function of the GDS is to provide nitrogen as a purge gas to the experiment furnaces via interface with the SSF Lab Nitrogen System , provide argon as a process gas for the furnace samples, provide venting of the furnace gases via interface with the SSF Vacuum Exhaust System (VES), and provide contamination monitoring of the waste exhaust gases and the argon process gas to the furnaces.

The subsystem interface schematics for the TCS, PCDS, GDS, and DMS developed during the SSFF Core Phase B effort are depicted in Figures 5.2.2-1 through 5.2.2-4.

5.2.3 Concept Trade Studies and Analyses

The Concept Trade Studies and Analyses task is the effort to determine the optimum SSFF system concept at the subsystem level. This involves the evaluation of the concepts selected during the Concept Identification task (Section 5.2.2) based on the varying constraints related to the SSFF development program. Trade studies and/or analyses reports will be generated to evaluate each of the subsystem concepts at a component level to determine the eventual subsystem design approach. The criteria for evaluating each of the subsystems will be different depending upon the nature of the subsystem, but will include the following basic criteria and/or constraints:

- Cost Constraints/Factors
- Schedule Constraints/Factors

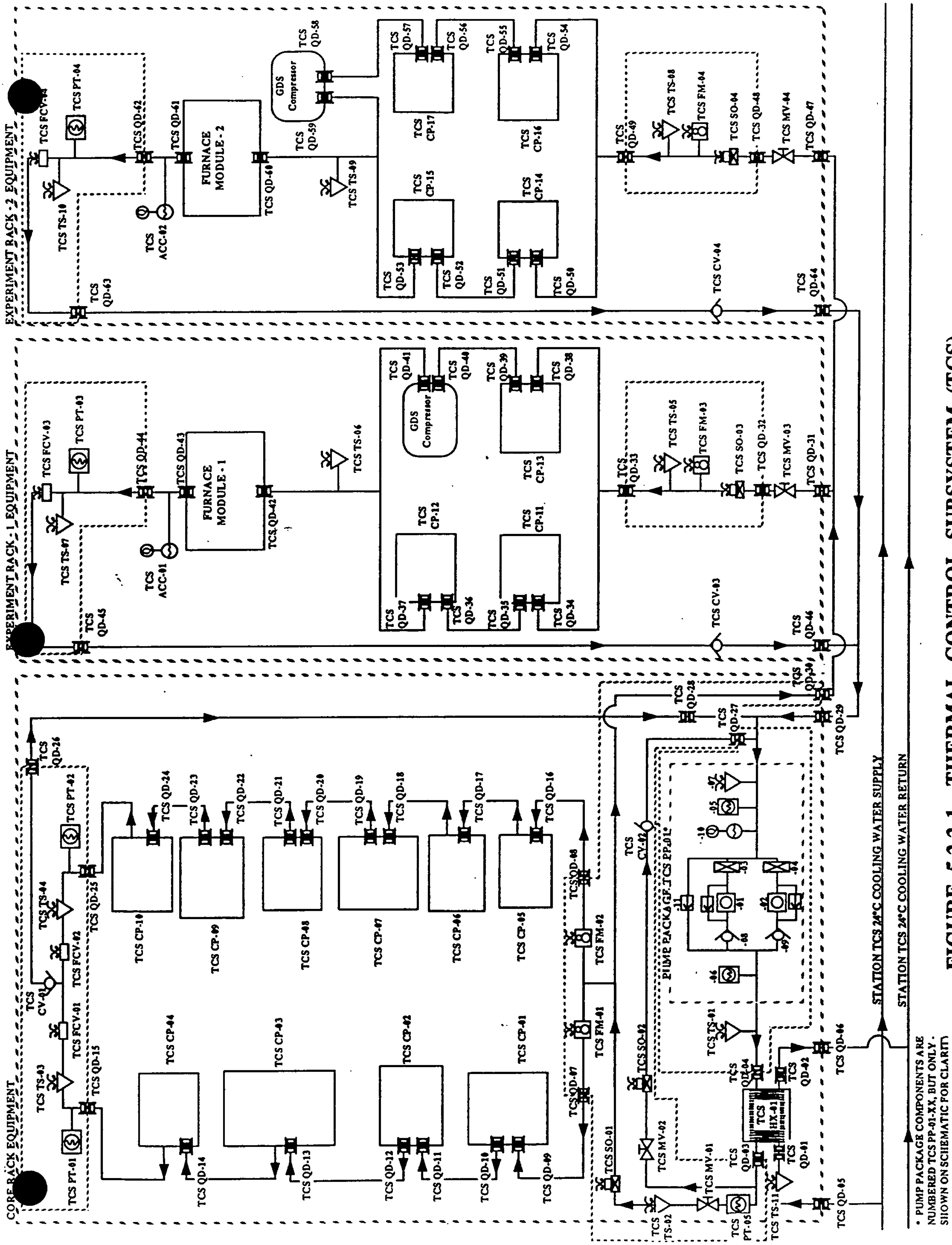


FIGURE 5.2.2-1 THERMAL CONTROL SUBSYSTEM (TCS) INTERFACE SCHEMATIC

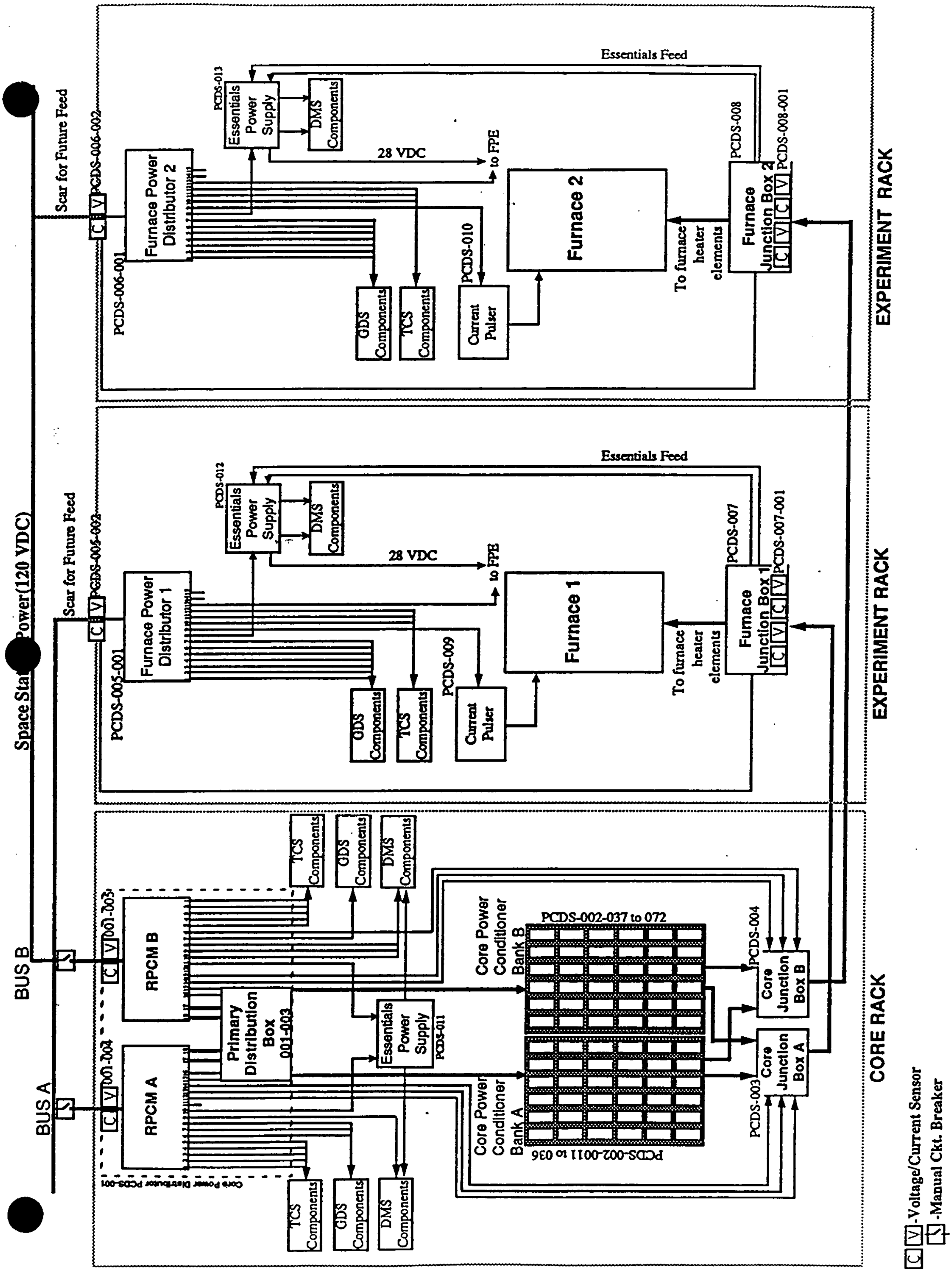


FIGURE 5.2.2-2 POWER CONDITIONING AND DISTRIBUTION SUBSYSTEM (PCDS) INTERFACE SCHEMATIC

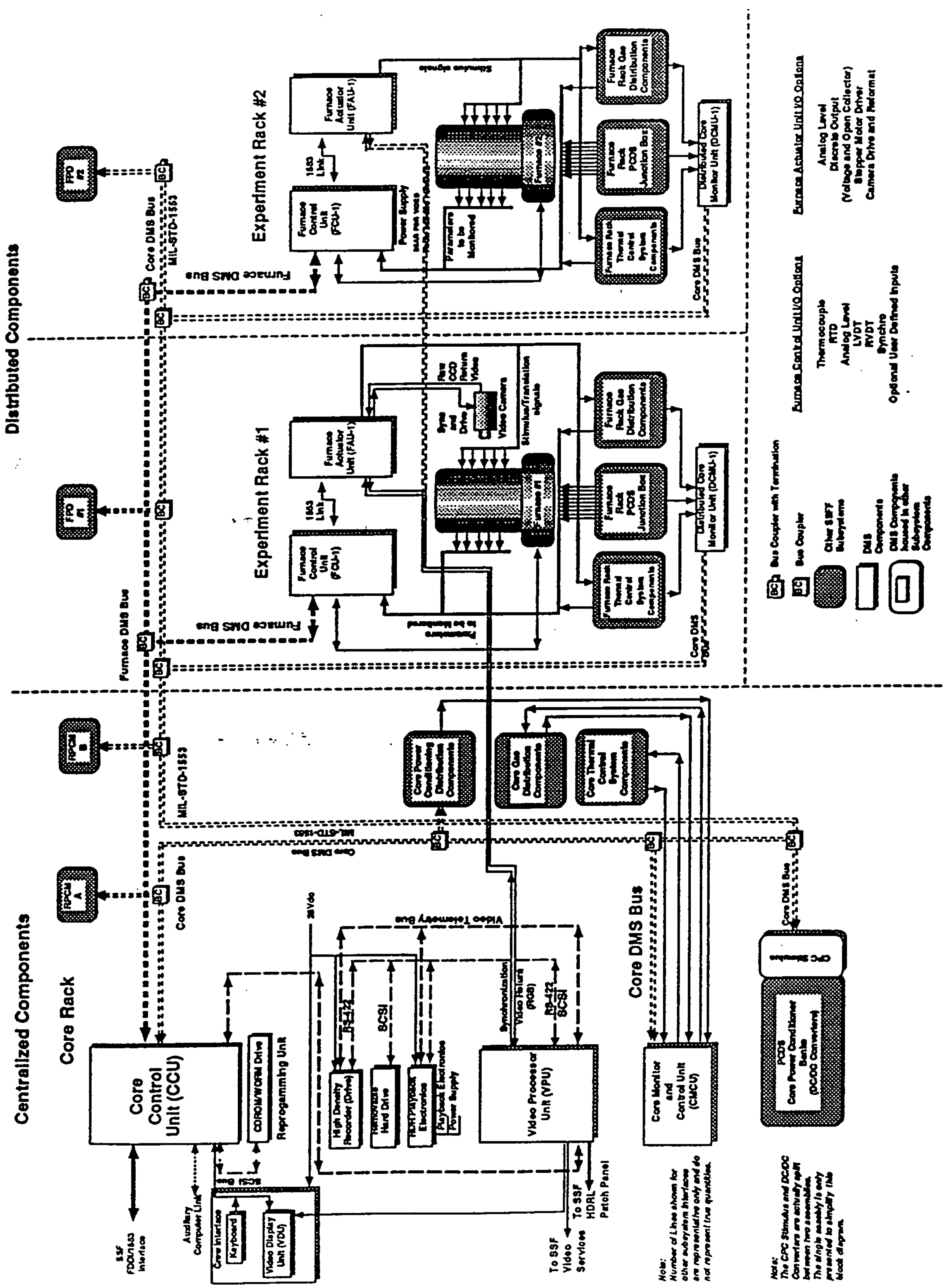


FIGURE 5.2.2-3 DATA MANAGEMENT SUBSYSTEM (DMS) INTERFACE SCHEMATIC

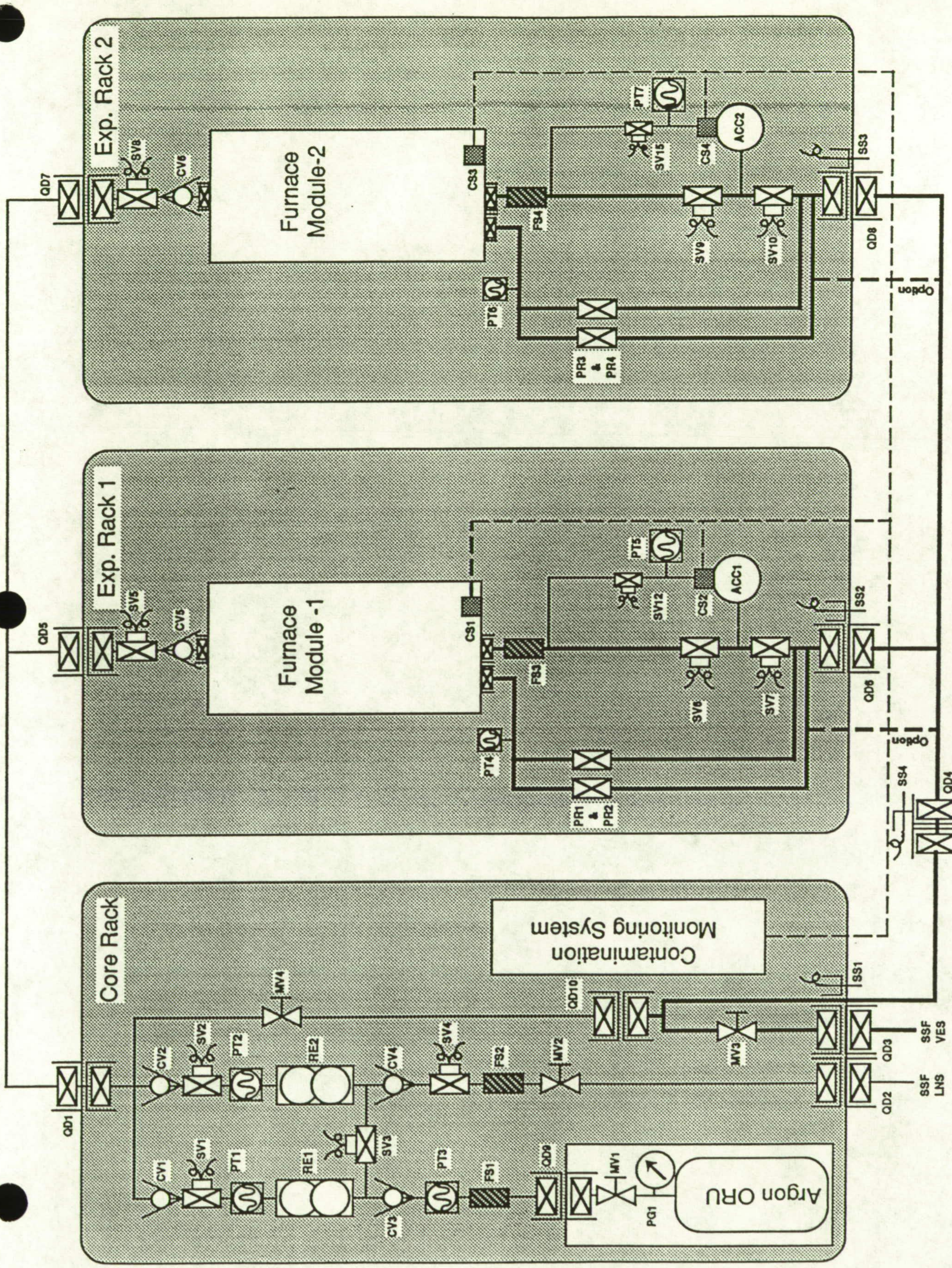


FIGURE 5.2.2-4 GAS DISTRIBUTION SUBSYSTEM (GDS) INTERFACE SCHEMATIC

- Technology Availability
- SSF Resources Constraints/Availability
- Science Requirements Satisfaction

5.2.4 Concept Selection

The trade studies and analyses conducted on each of the subsystem concepts will result in the recommendation of an SSFF Core system concept to proceed with design, development, test and engineering activities. The recommended system concept will require evaluation and input from Program Management prior to final concept selection based on review of the subsystem criteria analyses reports. Preliminary interface control documentation between the Core and the SSF, the Core and the FMs, and the integrated payload for each flight increment and the Logistics module. The documentation of interfaces for control over the course of the SSFF development will be detailed in section 6.1, Analytical Integration. This activity culminates with the Preliminary Requirements Review (PRR) for the Core. At the PRR, the requirements to which the SSFF Core will be developed will be finalized, so that the design phase of the Core development can begin.

5.2.5 Design and Development

The design and development tasks involved to produce a Core Flight Unit will include the evolutionary development of the Test Article and the GCEL hardware and software as described in sections 5.3 and 5.4, in addition to the following activities descriptions. The design and development activities will include the identification of the detailed physical interfaces to the SSFF Core equipment, the preliminary design analyses and subsequent documentation preparation for the Core and supporting equipment, the identification and definition of facilities requirements and their usage at each phase of the hardware development, the identification and design of Ground Support Equipment (GSE), the critical design analyses and subsequent documentation preparation, support of the activities for fabrication and/or procurement of subsystem components, the design and fabrication of trainers to support Core training as defined by the training function (Section 7.0), the identification of component and systems testing requirements and the support of testing activities, and the assembly, integration, and checkout of all SSFF hardware and software.

5.2.5.1 Interface Identification

The task of identifying the detailed physical interfaces to the SSFF Core equipment will require obtaining and reviewing information on the SSF physical interfaces, the FM interfaces, and the SSFF subsystem-to-subsystem interfaces. The information on the SSF interfaces will be available from the SSFP Payload Accommodations Handbook (PAH) Volumes I and II, and documents referenced within this PAH. A listing of the applicable documents from this handbook is provided in the Applicable Documents List provided in section 6.0 of this document. Technical Interchange Meetings (TIMs) and other informal telecons and routine communication (i.e., telephone conversations, technical memorandums, intermail computer correspondence, etc.) with the SSFP will summarily be required to clarify any interface questions that may arise during this task. Per the Phase B effort the SSFF Core has nine physical interfaces with the SSF to provide thermal resources, data and video capabilities, vacuum capabilities, processing gas resources, power resources, and monitoring capabilities. These direct interfaces to SSF systems include interface to the Thermal Control System, the Fiber Distributed Data Interface, SSF Video, the Lab Nitrogen System, the Vacuum Exhaust System, the High Data Rate Link, the Experiment Power System, and the Fire Detection and Suppression System. Figure 5.2.5.1-1 depicts the Phase B system overview interface schematic.

The identification of FM interfaces to the SSFF Core equipment will also require obtaining and reviewing existing detailed interface information. The Applicable Documents List in section 6.0 of this document will include the existing reference documentation to the FMs used in the Phase B effort. To obtain the interface information on the FMs will require detailed and descriptive TIMs, telecons and communication with the FM developers. Extreme care and mediation must be exercised to document the results and actions of these activities, so that no misunderstanding is incurred between the Core developer and the FM developers, which may perpetuate inaccurate design approaches. The Logistics section, 9.0, will detail the planning for the development and use of common equipment between each element developer. Per the Phase B effort, the Core/FM interfaces will include multiple interfaces to each of the Core subsystems as depicted in Figure 5.2.5.1-1.

The identification of SSFF Core equipment subsystem-to-subsystem interfaces will require internal communication of the SSFF Core developer's engineering disciplines, and will utilize the preliminary subsystem interface schematics and component identification lists developed during the Concept Identification task (section 5.2.2) to determine the

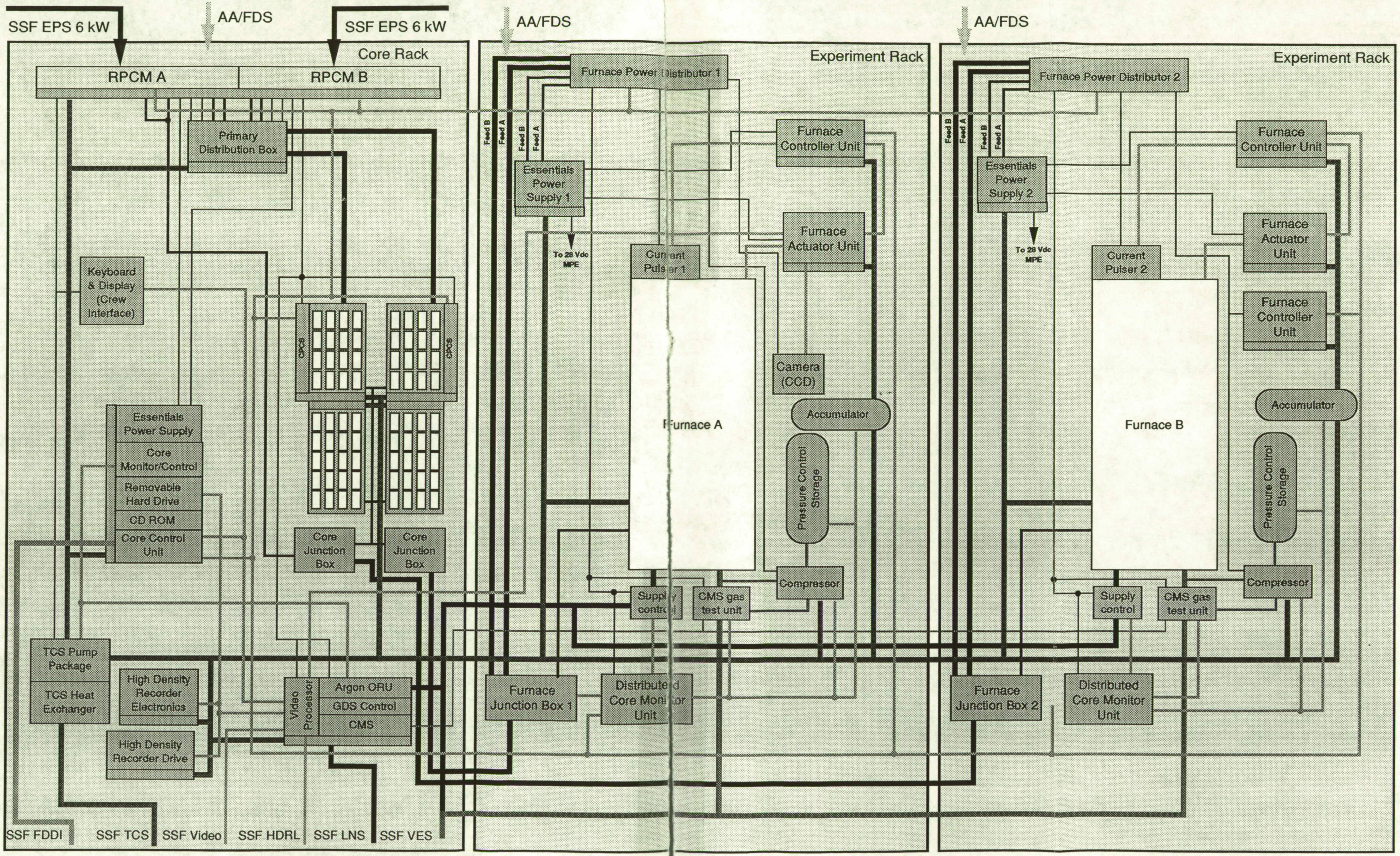


FIGURE 5.2.5.1-1 SSFF OVERVIEW INTERFACE SCHEMATIC

FOLDOUT FRAME 1.

FOLDOUT FRAME 2.

required interface rationale. The Core equipment subsystem-to-subsystem interface per the Phase B effort is also depicted in Figure 5.2.5.1-1.

As a result of reviewing the interface definition documentation and from participating in the various communication mechanisms, the SSFF Core developer will need to generate detailed SSFF Core-to-SSF resources interface schematics, SSFF Core-to-FM interface schematics, SSFF Core subsystem-to-subsystem interface schematics, and an overall interface schematic (similar to Figure 5.2.5.1-1) or configuration layout of the SSFF Core equipment interfaces to the SSF resources, the FMs, and internally as an output product. These schematics will be required to further the SSFF Core design analyses activities, and will be an update of the preliminary interface schematics developed during the Concept Identification effort. The individual subsystem interface schematics developed during the Phase B effort are referenced in section 5.2.2. These schematics will be used in the development of the preliminary interface control documentation to be provided at the PRR for evaluation by the SSFF project team members.

5.2.5.2 Preliminary Design and Documentation Preparation

The Preliminary Design Analyses and Documentation Preparation is the effort to begin the detailed analyses of the chosen subsystems, and to document the analyses for evaluation and review by the SSFP, NASA Program Management, FM developers, and the science community planning to use the SSFF (i.e., the Principal Investigators (PIs)) at the Preliminary Design Review (PDR). These inputs will be either updates to inputs submitted for PRR, or initial inputs. This effort will immediately begin after NASA approval of the design approach presented at PRR. The analyses and subsequent documentation required to be generated per the Integrated Requirements on Payloads (IROP) document will include the following deliverables for the PDR as a minimum:

- Parts Drawings
- Assembly and Integration Drawings
- Mass Properties Status Report
- Materials Identification & Usage List (MIUL)
- Power Profiles
- Thermal Analyses Report
- Command and Data Electrical Schematics
- Electrical Power Schematics

- Structural Analyses Report
- Phase 0/I Safety Package
- Software Requirements Document
- Preliminary Verification Plan

The activity to generate the Parts drawings for the SSFF Core subsystems will consist of reviewing inputs from previously developed schematics and documentation including the subsystem components lists, the subsystem schematics, the configuration layout, subsystems components materials lists, and physical interface definition (schematics and/or definition text and figures). Also, new inputs will be required including vendor specifications on known parts that will require procurement, and estimations on the mass of the components. The mass of the components will be more accurately defined by calculation once the parts drawings are completed, and will be submitted in the Mass Properties Status Report. The acquisition of data not internal to the SSFF Core developer will be obtained through TIMs, telecons, and routine communication with the proposed vendors, the FM developers, and applicable SSFP organizations. The number of parts drawings required can be estimated from the number of subsystem components identified during the Phase B effort and listed in the Tables 5.2.5.2-1 through 5.2.5.2-5.

The activity to generate the Assembly and Integration drawings for the SSFF Core will consist of reviewing inputs developed in the previous WBS elements described, including parts drawings, SSFF-to-SSF resources interface schematics, SSFF-to-FM interface schematics, SSFF subsystem-to-subsystem interface schematics, the configuration layout (overall schematic), and rack physical interface definition. The assembly and integration drawings will include subsystem assembly drawings and the integration drawing of the SSFF Core subsystems interfacing with the SSF resources and the FMs in the proposed rack complement configuration. The acquisition of data to substantiate the production of the assembly and integration drawings that are not provided from internal SSFF Core developer sources, will be obtained through TIMs, telecons and routine communication. The number of assembly drawings required should be consistent with the number of overall SSFF Core subsystems, but may require additional drawings to provide specific detail on subsystem subassemblies.

The activity to generate the Mass Properties Status Report will require obtaining and reviewing information including the subsystem components lists, the materials breakdown of the components, the component geometry, and any vendor specifications on components or equipment that will be procured as inputs. The development of the Mass Properties

TABLE 5.2.5.2-1 MECHANICAL/STRUCTURAL SUBSYSTEM (MSS) COMPONENT IDENTIFICATION AND MASS ESTIMATION (page 1 of 2)

Equipment Nomenclature	Qty	Unit Mass (kg)	Total Mass (kg)
Interconnect Tray Assembly	1	72.7	72.7
Core Rack:	1	224.9	224.9
TCS MSS	1	22.9	22.9
PCDS MSS	1	31.8	31.8
GDS MSS	1	21.7	21.7
DMS MSS	1	56.2	56.2
Rack (Aluminum)	1	84.0	84.0
Supply Diffuser	1	0.3	0.3
Inter-Rack Ducting	1	4.0	4.0
Fire Suppr. Control Valve	1	1.2	1.2
Fire Suppr. Disprs'n Tubing	1	0.6	0.6
Control/Input Panel	1	0.7	0.7
Fire Suppr. Distrib. Tubing	1	0.6	0.6
Pressure Release Valve	1	0.9	0.9
Video I/O Control Panel	1	TBD	TBD
Experiment Rack-1:			
Exp Rack-1 Distrib. MSS	1	28.4	28.4
Experiment Rack-1:	1	128.7	128.7
Rack (Aluminum)	1	119.7	119.7
Inter-Rack Ducting	1	4.0	4.0
Supply Diffuser Ducting	1	0.4	0.4
Return Diffuser Ducting	1	0.6	0.6
Control Valve Driver Box	1	TBD	TBD
Fire Suppr. Control Valve	1	1.2	1.2
Fire Suppr. Disprs'n Tubing	1	0.6	0.6
Control/Input Panel	1	0.7	0.7
Fire Suppr. Distrib. Tubing	1	0.6	0.6
Pressure Release Valve	1	0.9	0.9
Video I/O Control Panel	1	TBD	TBD

TABLE 5.2.5.2-1 MECHANICAL/STRUCTURAL SUBSYSTEM (MSS) COMPONENT IDENTIFICATION AND MASS ESTIMATION (page 2 of 2)

Equipment Nomenclature	Qty	Unit Mass (kg)	Total Mass (kg)
Experiment Rack-2:			
Exp Rack-2 Distrib. MSS	1	28.4	28.4
Experiment Rack-2:	1	128.7	128.7
Rack (Aluminum)	1	119.7	119.7
Inter-Rack Ducting	1	4.0	4.0
Supply Diffuser Ducting	1	0.4	0.4
Return Diffuser Ducting	1	0.6	0.6
Control Valve Driver Box	1	TBD	TBD
Fire Suppr. Control Valve	1	1.2	1.2
Fire Suppr. Disprs'n Tubing	1	0.6	0.6
Control/Input Panel	1	0.7	0.7
Fire Suppr. Distrib. Tubing	1	0.6	0.6
Pressure Release Valve	1	0.9	0.9
Video I/O Control Panel	1	TBD	TBD
TOTAL MSS:			**611.8**
TOTAL CORE RACK:			**224.9**
TOTAL EXPERIMENT RACK-1:			**157.1**
TOTAL EXPERIMENT RACK-2:			**157.1**

TABLE 5.2.5.2-2 THERMAL CONTROL SUBSYSTEM (TCS) COMPONENT IDENTIFICATION AND MASS ESTIMATION

Equipment Nomenclature	Qty	Unit Mass(kg)	Total Mass(kg)
Centralized Equipment:			
Heat Exchanger	1	13.6	13.6
Pump Package	1	15.9	15.9
Flow Meters	2	0.8	1.5
Flow Control Valves	2	1.9	3.7
Temperature Sensors	5	0.1	0.5
Pressure Transducers	3	0.5	1.5
Custom Coldplates	4	6.0	24.0
Type 5 Coldplates	2	1.6	3.3
Pwr Mod Coldplate-Upper	2	6.0	12.0
Pwr Mod Coldplate-Lower	2	4.9	9.8
Plumbing (meters)	25	0.5	13.6
Quick Disconnects	30	0.1	3.0
Check Valves	2	0.1	0.1
Manual Valves	2	0.1	0.3
Shutoff Valves	2	1.9	3.7
Water	1	10.0	10.0
Distributed Equipment:			
Modified -7 Coldplates	7	3.9	27.3
Temperature Sensors	6	0.1	0.5
Pressure Transducers	2	0.5	1.0
Flow Meters	2	0.8	1.5
Flow Control Valves	2	1.9	3.7
Check Valves	2	0.1	0.1
Manual Valves	2	0.1	0.3
Shutoff Valves	2	1.9	3.8
Plumbing (meters)	25	0.5	13.6
Accumulators	2	2.7	5.4
Quick Disconnects	34	0.1	3.4
Water	1	14.0	14.0
TOTAL TCS:			**191.3**
TOTAL CORE RACK TCS:			**116.5**
TOTAL EXPERIMENT RACK-1 TCS:			**35.4**
TOTAL EXPERIMENT RACK-2 TCS:			**39.3**

TABLE 5.2.5.2-3 POWER CONDITIONING AND DISTRIBUTION SUBSYSTEM (DMS) COMPONENT IDENTIFICATION AND MASS ESTIMATION

Equipment Nomenclature	Qty	Unit Mass (kg)	Total Mass (kg)
Centralized Equipment:			
Core Pwr Distributor (CPD)	1	42.0	42.0
-RPCMs	2	6.0	12.0
-Primary Distribution Box	1	30.0	30.0
Core Power Condit'nr (CPC)	1	47.2	47.2
-CPC Bank A (Top)	1	-	-
-CPC Bank A (Bottom)	1	-	-
-CPC Bank B (Top)	1	-	-
-CPC Bank B (Bottom)	1	-	-
Core Junct Box-A (CJB-A)	1	4.5	4.5
Core Junct Box-B (CJB-B)	1	4.5	4.5
Essentials Power Supply	1	3.2	3.2
Voltage/Current Sensors	4	0.5	2.0
Line & Connectors	1	11.3	11.3
Distributed Equipment:			
Current Pulsing Equip.	2	13.6	27.2
Furnace Pwr Dist. (FPD)	2	7.3	14.5
Furnace Junction Box (FJB)	2	9.5	19.1
Essentials Power Supplies	2	4.8	9.7
Voltage/Current Sensors	132	0.5	66.0
Line & Connectors	1	7.7	7.7
TOTAL PCDS:			**258.9**
TOTAL CORE RACK PCDS:			**114.7**
TOTAL EXPERIMENT RACK-1 PCDS:			**72.1**
TOTAL EXPERIMENT RACK-2 PCDS:			**72.1**

TABLE 5.2.5.2-4 DATA MANAGEMENT SUBSYSTEM (DMS) COMPONENT IDENTIFICATION AND MASS ESTIMATION

Equipment Nomenclature	Qty	Unit Mass(kg)	Total Mass(kg)
Centralized Equipment:			
Core Control Unit (CCU)	1	29.0	29.0
Removable Hard Drive	1	22.0	22.0
CDROM/WORM Drive	1	7.7	7.7
High Density Recorder	1	57.0	57.0
Video Processor Unit (VPU)	1	27.0	27.0
Core Monitor/Control Unit (CMCU)	1	20.0	20.0
Crew Interface	1	23.0	23.0
CPCS	2	18.0	36.0
Cabling	AR	TBD	20.0
Distributed Equipment:			
Furnace Control Unit (FCU)	3	29.0	87.0
Furnace Actuator Unit (FAU)	2	29.0	58.0
DCMU	2	20.0	40.0
Cabling	AR	TBD	13.0
TOTAL DMS:			**439.7**
TOTAL CORE RACK DMS:			**241.7**
TOTAL EXPERIMENT RACK-1 DMS:			**84.5**
TOTAL EXPERIMENT RACK-2 DMS:			**113.5**

TABLE 5.2.5.2-5 GAS DISTRIBUTION SUBSYSTEM (GDS) COMPONENT IDENTIFICATION AND MASS ESTIMATION

	Nomenclature	Qty	(kg)	(kg)
Centralized Equipment:				
	Argon+bottle (consumable)	1	17.5	17.5
	Latching Solenoid Valve	4	1.0	4.0
	Manual Valve, 1/4"	4	0.2	0.9
	Manual Valve, 1"	1	2.4	2.4
	Regulator	2	0.9	1.8
	Filter, 1/4"	2	0.2	0.3
	Pressure Transducer	3	0.2	0.5
	Pressure Gauge	1	0.5	0.5
	Contamination Monitor	1	18.0	18.0
	Check Valve, 1/4"	4	0.2	0.6
	QD (with cap), 1/4"	4	0.1	0.4
	QD (with cap), 1"	2	1.6	3.2
	Plumbing/Hose/Fittings	TBD	TBD	6.0
Distributed Equipment:				
	Latching Solenoid Valve	12	1.0	12.0
	Pressure Relief Valve	4	0.5	1.8
	Filter, 1"	2	3.6	7.3
	Compressor	2	15.0	30.0
	Storage Tank	2	17.5	35.0
	Accumulator	2	8.0	16.0
	Check Valves	4	0.2	0.8
	CM Sensors	4	3.0	12.0
	Pressure Transducer	6	0.2	1.0
	QD (with cap), 1/4"	2	0.1	0.2
	QD (with cap), 1"	2	1.6	3.2
	Check Valve, 1/4"	2	0.2	0.3
	Plumbing/Hose/Fittings	TBD	TBD	2.0
TOTAL GDS:				**177.8**
TOTAL CORE RACK GDS:				**56.2**
TOTAL EXPERIMENT RACK-1 GDS:				**60.8**
TOTAL EXPERIMENT RACK-2 GDS:				**60.8**

Status Report for the PDR level inputs will include calculating the component masses based on the materials used and the component geometry, obtaining the masses of components on those components or subassemblies that will be procured, calculating the centers of gravity for each of the components, and calculating the overall SSFF system center of gravity in the Core rack. Information from the FM developers will also be required as input to allow the calculation of the FM rack (ER) equipment centers of gravity. This information will be obtained through TIMs, telecons, and routine communication. Representative component masses for the SSFF Core subsystems as identified during the SSFF Phase B effort are included in Tables 5.2.5.2-1 through 5.2.5.2-5.

The activity to prepare the Materials Identification and Usage List (MIUL) for the SSFF Core equipment will consist of reviewing inputs from the design engineering discipline on the identification of subsystem component materials, and vendor materials specifications on equipment that will be procured. The use of MSFC-HDBK-527 (latest revision) will be required as well as access to the MSFC Materials database to evaluate the design materials for their specific environments and functional applicability. Consultation with MSFC on the materials database will also be required. The MIUL will be utilized in the analyses to identify hazards which are associated with the material usage during SSFF Core ground and flight activities including testing, checkout, and on-orbit operations.

The activity to prepare power profiles will initiate by obtaining, reviewing, and analyzing information including the identification of the SSFF Core equipment power consumption at the component level, the identification of the FM equipment power consumption at the component level, the Functional Objectives (FOs) for the FM activation/operation, the SSFF Core equipment FOs, and the SSF power availability. The acquisition of this information will require participation in TIMs, telecons, and through routine communication. The power profiles will depict the cumulative power consumption for each step identified in the FOs. The power profiles will be useful in assessing the overall power usage timeline in the USL, and will be utilized for input power values during the thermal analyses on the SSFF Core equipment. A representative power profile per the Phase B effort is presented in Figure 5.2.5.2-1.

The activity to prepare the Thermal Analyses Report will commence by obtaining and reviewing furnace heat loads information, the SSFF Core subsystems components heat loads information, the identification/definition of the SSF water cooling capability in the USL, the SSF avionics air cooling capability identification/definition, and the interface and subsystem component configuration layout/overall schematic including coldplate-to-equipment components locations and ducted air components locations. The thermal analyses developed from these inputs will include evaluation of heat rejection rates of the

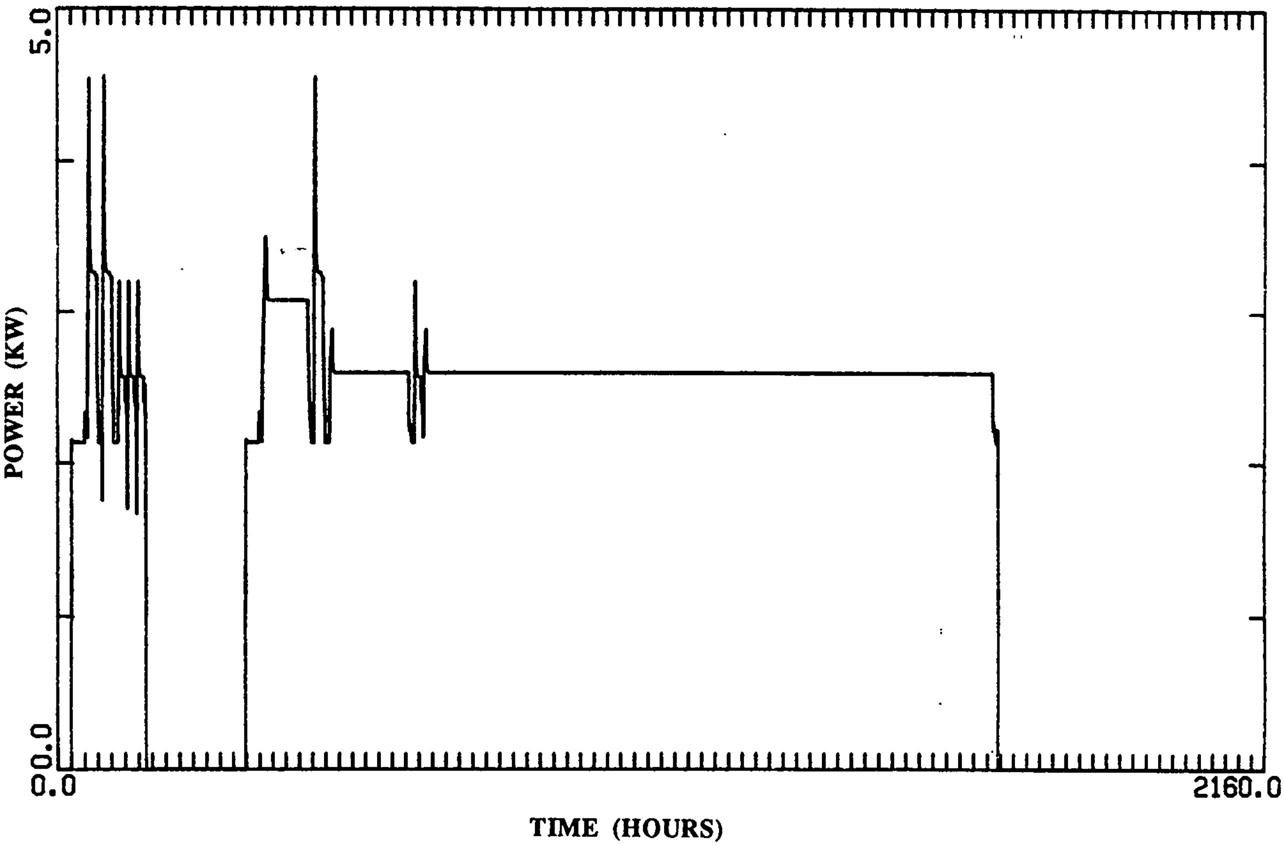


FIGURE 5.2.5.2-1 TYPICAL SSFF POWER PROFILE

total heat load generated by the SSFF, and will be used as input to evaluate the overall heat loads of the integrated USL. The acquisition of data not developed by the SSFF Core developer will be accomplished through attending TIMs with the FM developers and the SSFP organizations, participating in telecons with the FM developers and SSFP organizations, and through routine communication. Representative thermal profiles for the SSFF generated during the Phase B effort are included in Figure 5.2.5.2-2, and representative heat loads for the SSFF Core subsystems are presented in Table 5.2.5.2-6.

The activity to generate command and data circuit schematics for SSFF Core equipment is required to analyze the design of data command and control, data storage, and data dissemination as required by the FMs and the internal SSFF Core subsystems. The activities required to develop these schematics will include reviewing and obtaining all FM data requirements, all SSFF Core subsystems requirements, the FM FOs, the SSFF Core FOs, the circuit specifications from vendors on procured equipment, the functional interface definition of the SSF data system resources, the identification of software and its usage, and the functional interface definition of the SSFF Core-to-FMs and the SSFF Core subsystem-to-subsystem interfaces. The acquisition of the input information for developing the command and data circuit schematics will be accomplished via scheduling and attending TIMs, support of formal telecons, and routine communication with the FM developers and applicable vendors.

The activity to generate electrical power circuit schematics is required to analyze the design of power circuits for the SSFF Core subsystem components and the FMs equipment components. The activities required to develop these schematics will include obtaining, reviewing, and analyzing SSFF Core subsystem component power consumption, FM component power consumption, the FM FOs, the SSFF Core equipment FOs, the SSFF configuration layout, vendor items specifications, and the limits of the SSF power resource availability. The acquisition of the input information for developing the electrical power circuit schematics will be accomplished via scheduling and attending TIMs, support of formal telecons, and routine communication with the FM developers and applicable vendors.

The activity to generate a Structural Analyses Report will begin with obtaining and reviewing SSFF Core subsystems parts drawings, the SSFF Core assembly drawings, the component mass information including the FM components, the SSFF Core MIUL, and the identification of the applicable loads environments. The FM equipment component masses will be required to evaluate the loads effect on the SSFF Core-supplied rack (ER) structure in which the FMs will be mounted. The input information required to prepare the structural analyses that is not supplied from SSFF Core developer internal sources, will by

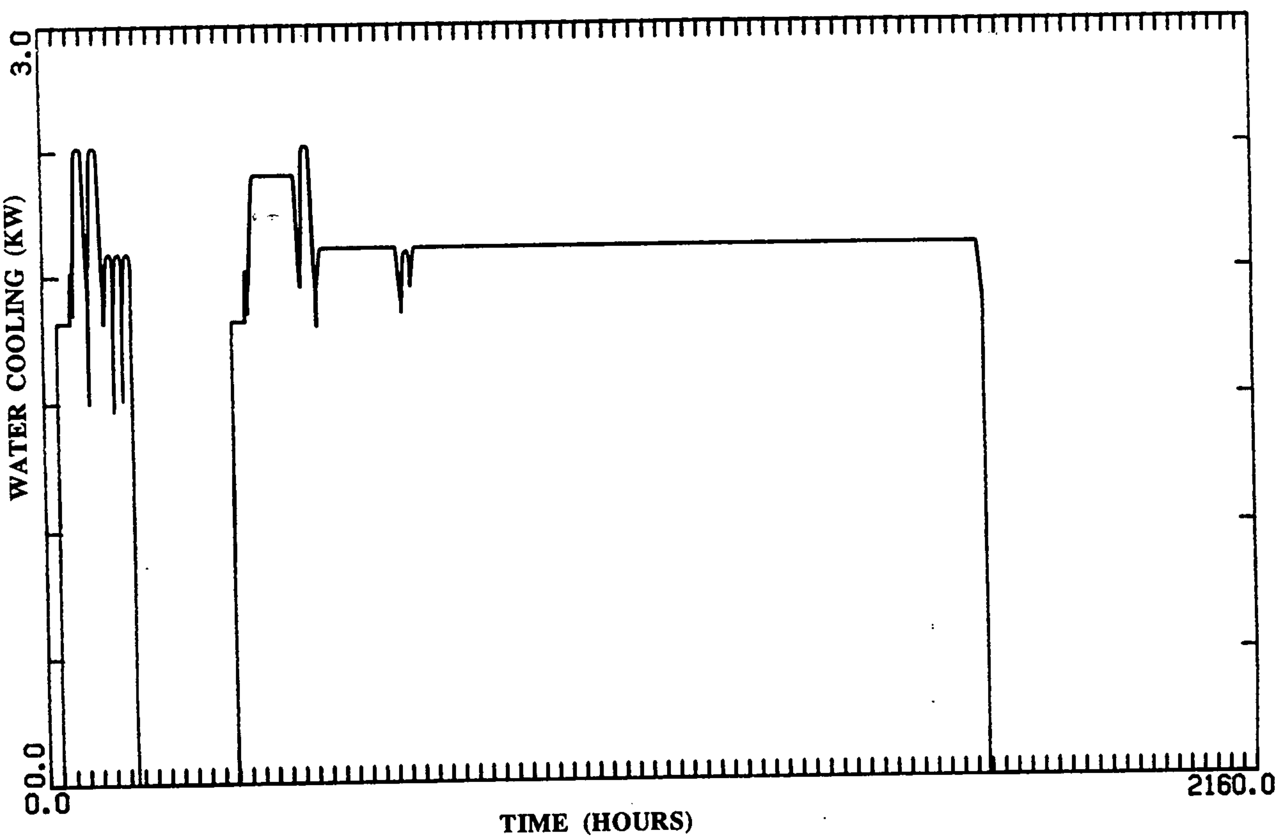


FIGURE 5.2.5.2-2 TYPICAL THERMAL PROFILE

TABLE 5.2.5.2-6 TYPICAL SSFF CORE SUBSYSTEM HEAT LOADS (page 1 of 2)

WATER-COOLED: Subsystem Equipment (Quantity)	Heat Load (W)	Subtotal (W)
Thermal Control Subsystem:		
Coolant Pump Assembly (1)	132	
*Flow meters (4)	3	
*Flow Control Valves (4)	1	
*Temperature Sensors (11)	1	
*Pressure Transducers (5)	3	
*Shutoff Valves (4)	1	
		132
Gaseous Distribution Subsystem:		
Contamination Monitor (1)	150	
Compressors (2)	20	
		170
Data Management Subsystem:		
Furnace Control Unit (3)	309	
Furnace Actuator Unit (2)	240	
Core Control Unit (1)	155	
Removable Hard Drive (1)	84	
CD/ROM (1)	70	
High Density Recorder (1)	204	
Core Monitor and Control Unit (1)	43	
Video Processor (1)	145	
CPCS	88	
		1338
Power Conditioning and Distribution Subsystem:		
Core Power Distribution (1)	111	
Essentials Power Supplies (3)	386	
Core Power Conditioner (1)	1300	
		1797
****TOTAL SUBSYSTEM WATER-COOLED HEAT LOAD =**		**3437**
Furnace Module -1		1500
Furnace Module -2		2150
TOTAL SSFF WATER-COOLED HEAT LOAD =		**7087**

* Assume that on TCS valves, sensors, etc., half the heat is dissipated through the water cooling loop and half is dissipated through Avionics Air. Other subsystems' valves, etc., are cooled by Avionics Air only.

** Heat load from TCS valves, sensors, etc., is neglected in water cooling analysis since heat load from these is insignificant compared to total water-cooled heat load.

TABLE 5.2.5.2-6 TYPICAL SSFF CORE SUBSYSTEM HEAT LOADS (page 2 of 2)

AVIONICS AIR-COOLED: Subsystem Equipment (Quantity)	Heat Load (W)	Subtotal (W)
Thermal Control Subsystem:		
*Flow meters (4)	3	
*Flow Control Valves (4)	1	
*Temperature Sensors (11)	1	
*Pressure Transducers (5)	3	
*Shutoff Valves (4)	1	
		8
Gaseous Distribution Subsystem:		
Latching Solenoid Valves (16)	29	
Manual Valve (1)	2	
Pressure Transducers (3)	3	
Pressure Transducers (6)	12	
CM Sensors (4)	1	
		47
Data Management Subsystem:		
Crew Interface (1)	60	
DCMU (2)	96	156
Power Conditioning and Distribution Subsystem:		
Line and Connectors	639	
Current Pulsing Equipment (2)	80	
Furnace Power Distributors (2)	37	
Voltage/Current Sensors (136)	136	
		892
TOTAL SSFF AVIONICS AIR COOLED HEAT LOAD =		**1103**

* Assume that on TCS valves, sensors, etc., half the heat is dissipated through the water cooling loop and half is dissipated through Avionics Air. Other subsystems' valves, etc., are cooled by Avionics Air only.

gathered via TIMs, telecons, and routine communication from the FM developers and the SSFP as applicable. From all of the input data received the SSFF Core developer will analyze the preliminary structural design and produce the initial structural analyses input including the identification of the safety-critical structures, the preparation the dynamic model and a description of the model for the SSFF Core equipment, and preparation of the dynamic test plan for the structures. Also, an output product required from the SSFF Core developer is the identification of potential stowage items (stowage list) and the identification of the stowage requirements including any unique containers and/or packaging. The stowage list will evolve to include items identified as Orbital Replacement Units (ORUs). An ORU identification task is required as an iterative process during the development of the SSFF, and will be addressed in detail in section 9.0, Logistics.

The activity to prepare the phased safety documentation for each formal safety review (i.e., Phase 0/I, II, and III, respectively) is an analytical integration function activity. The DDT&E function will supply support to the analytical integration function in the preparation of the safety documentation, and presentation material for the safety reviews.

The activity to prepare a Software Requirements Document will require reviewing and understanding the software being developed. The development of software for the SSFF Core equipment is required to perform several functions including the initialization of hardware and software, diagnostics and troubleshooting, command processing, video processing, monitoring and control of the SSFF Core subsystem components, downloading of software and data, uplink/downlink capabilities, and data storage retrieval. The activities to initiate the software development will include obtaining and reviewing the functional requirements of the FM specific software, the FM FOs, the SSFF Core FOs, the functional definitions of the SSFF Core components and GSE in which the software will be maintained and required, the SSF data system interface definitions and functional capabilities, and the SSFF Core configuration layout. The acquisition of FM data inputs and SSF data system interfaces inputs will require communication between the FM developers and the SSFP, respectively, via TIMs, telecons, and routine communication mechanisms.

The activity to prepare the verification planning documentation for each required input and subsequent update will be the responsibility of the analytical integration function. The DDT&E function will supply support to the analytical integration function in the preparation of the Verification Plan, and will perform the activities (analyses, tests, and inspections) to closeout the verification items prior to the IRR for each element.

5.2.5.3 Critical Design and Documentation Preparation

The Critical Design Analyses and Documentation Preparation for the SSFF Core is the effort to finalize the detailed analyses of the chosen design approach, and to document the analyses for evaluation and review by the SSFP, NASA Program Management, FM developers, and the PIs at the CDR. These design inputs will either be updates to documentation submitted at the PDR, or new inputs. The analyses and subsequent documentation required to be generated per the IROP document will include the following deliverables for the CDR as a minimum:

- Baseline Issue Parts Drawings
- Baseline Issue Assembly and Integration Drawings
- Latest Quarterly Update of Mass Properties Report
- Final Materials Identification and Usage List
- Updated Power Profiles
- Baseline Issue Command and Data Management Schematics
- Baseline Issue Electrical Power Interface Schematics
- Updated Structural Analyses Report
- Phase II Safety Packages
- Updated Software Requirements Document
- Baseline Issue Verification Plan

The activities required to perform the updated design and analyses, and to generate these documentation products for review at the CDR, will be similar to the PDR activities with respect to the mechanics of performing the tasks. As a result of the design maturity, the complexity of the documentation products will be significant in comparison to the PDR activities.

5.2.5.4 Certification Acceptance/Integration Readiness Activities

The DDT&E function will provide updates per approved RID comments of the design inputs submitted at CDR immediately after CDR to baseline the controlling documentation (i.e, ICDs and Verification Plans) of the design, and begin the as-built development and documentation. These controlling documents will be prepared and controlled by the analytical integration function as described in Section 6.1, Analytical

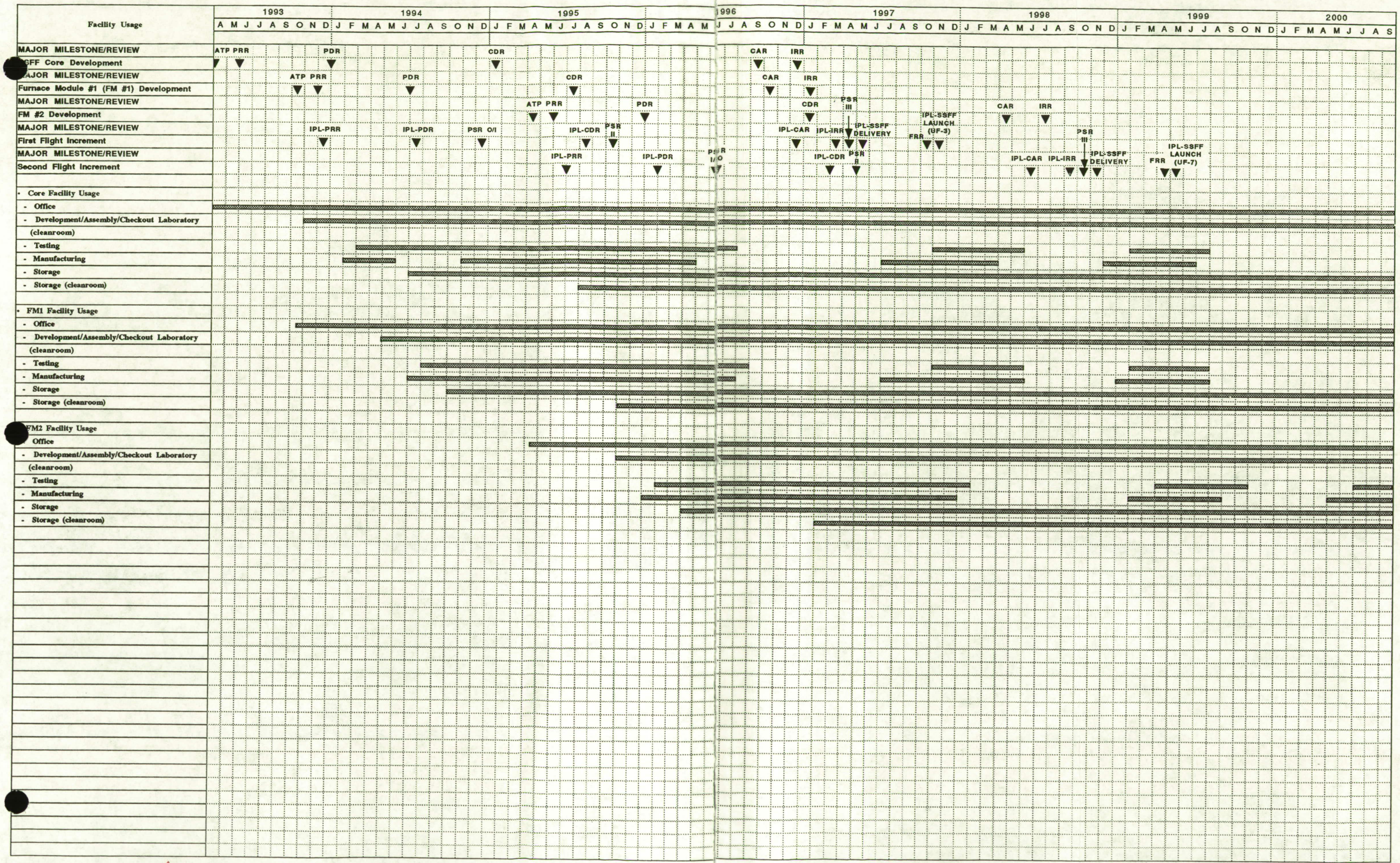
Integration. The DDT&E function activities in preparation of the CAR and IRR will include the finalization of the GCEL Qualification Unit for qualification testing activities, the preparation of corresponding analyses reports, the performance of qualification testing to show compliance with verification requirements, and the preparation of subsequent test reports to support verification requirements closeouts at IRR. The Phase III Safety Package development by the analytical integration function will require these inputs at this time for closeout, as the Phase III Safety Review will also take place during this period.

The DDT&E function will also provide sustaining engineering at this point to support the manufacturing, analytical integration, physical integration, training, operations, and logistics functions to produce and certify the hardware and software for flight. The activities of these functions are located in the appropriately titled sections of this document.

5.2.5.5 Facilities Requirements and Usage Identification

The activities to be performed to allow identification of applicable facilities area layouts, support resources requirements, and unique environmental conditions to support the SSFF Core development will be described in this section. The facility categories to be defined include office facilities, manufacturing/fabrication facilities, laboratory facilities, testing facilities, and storage facilities. A representative schedules for the usage of these types of facilities is presented in Figure 5.2.5.5-1. The selection of the types of facilities to be used in the development of the SSFF will be based on examination of the cost estimates to acquire, operate, and maintain the facilities versus requirements for each type of facility, and will require the maximum use of existing central facilities and support resources to minimize the development costs and the impact on schedule.

Office facilities and support resources will be required to perform common daily office activities including performing design analyses, preparing documentation and drawings, communicating with the FM developers and applicable SSFP organizations, and management activities. Office facilities and support resources will also be required to support major reviews and on-site customer office accommodations during reviews, testing, integration or checkout. The inputs required to perform the task to identify office facilities requirements will include the design master schedule, the personnel requirements to support the schedule tasks, the office equipment required to support the design and development tasks, and the support resources requirements. The personnel requirements inputs will be derived from the review and assessment of the design activities, manufacturing/fabrication activities support requirements, testing activities support requirements, assembly and integration activities support requirements, and checkout



FOLDOUT FRAME 1

FIGURE 5.2.5.5 TYPICAL FACILITY USAGE SCHEDULE

FOLDOUT FRAME 2

activities support requirement . The output product as a result of reviewing the listed inputs will be the determination of the area requirements and the layout of the identified office equipment with respect to support resources, and the identification of personnel stations. Representative office equipment requirements are presented in Table 5.2.5.5-1.

The identification of manufacturing/fabrication facilities to support the SSFF Core design and development is the next activity to be defined. The manufacturing/fabrication facilities are required to develop the SSFF Core subsystem components, GSE, and special test equipment that will be used to assemble and checkout the SSFF Core. The inputs required to perform the facilities identification includes the lists of subsystem components to be produced, the subsystem production schedules, lists of GSE and special test equipment components to be produced, GSE and special test equipment component production schedules, the manufacturing equipment required to produce the components, the personnel support requirements, and the support resources requirements. The identification of GSE and special test equipment required to support the SSFF Core development is detailed in section 5.2.5.6, and representative manufacturing equipment is presented in Table 5.2.5.5-2. The resulting output from review and analyses of the listed inputs will include the determination of the area required and the appropriate layout for the equipment, personnel, and resources to support the manufacturing/fabrication of SSFF Core hardware, as well as GSE and special test equipment hardware.

Laboratory facilities will be required to perform assembly of the SSFF Core subsystems, integration of the subsystems, integration of the GSE with the SSFF Core subsystems, and checkout of the SSFF Core and GSE functions and capabilities. The inputs required to identify the laboratory facilities requirements include SSFF Core and GSE components lists, the schedules for the assembly, integration, and checkout activities of each equipment category, the assembly and integration drawings for the SSFF Core and GSE, the schedule for the maintainability of all articles of Core-related equipment, unique environmental control requirements, the personnel support requirements, and support resources requirements. As a result of the review and analyses of the listed inputs, the determination of the area required and the appropriate layout for the equipment,personnel and resources to support assembly, integration, and checkout activities will be achieved.

Testing facilities will be required to perform component level testing to ensure safe equipment operation during the assembly, integration, and checkout activities, and to determine component use viability for its specific operational environment. The inputs required to evaluate the testing facilities requirements for the SSFF Core equipment components and the GSE components testing will include the identification of the components that require testing, the types of testing to be performed, the testing schedule

TABLE 5.2.5.5-1 TYPICAL OFFICE EQUIPMENT REQUIREMENTS

OFFICE EQUIPMENT ITEM	QUANTITY
Desk	50
Filing Cabinet	50
Book Shelves	50
Tables (3' x 6')	35
Phone	50
Design Work Station	10
Drawing Table	5
Computer Table	35

TABLE 5.2.5.5-2 TYPICAL MANUFACTURING/FABRICATION FACILITIES REQUIREMENTS

General Purpose Machine Shop
Welding Shop
Sheet Metal Shop
Alodine Facility
Paint Shop - Flight Qualification
Mechanical Inspection Facility
Electronics Fabrication Shop - Flight Qualified
Vacuum Bake Facility
Electronics Test Laboratory
100K Clean Room

as applicable to the overall design master schedule, the equipment needed to support the required testing, the support facilities requirements, unique environmental control requirements, and the personnel support requirements. The identification of components that will require testing, the personnel support requirements, the support resources requirements, and the necessary equipment requirements to perform the testing will be derived during the activities to support the Core verification. These inputs will allow the determination of the area required and the appropriate layout required for the test configurations (test equipment and test specimen layout).

Storage facilities will be required to accommodate equipment that is not in use or waiting to be used, so that no damage may inadvertently be rendered. This includes all phase-developed Core subsystem equipment, GSE, and special test equipment. The inputs required to determine the storage facilities requirements include the lists of equipment assemblies and components, parts drawings of the equipment items, assembly and integration drawings of equipment assemblies, unique environment control for the equipment when not in use, and the usage schedules for all equipment identifying the time and duration the equipment is not in use. The required storage facilities area to accommodate the equipment will be identified as a result of reviewing and analyzing the listed inputs.

5.2.5.6 GSE Identification and Design

GSE is required to support the testing, assembly, integration, and checkout operations for the Core. This GSE includes equipment to provide SSF resources simulation, FM loads and interface simulation, handling capabilities, structural support capabilities, special test apparatus, and special tooling. The identification of equipment concepts for each of the categories listed above is the initial step in developing all GSE. The activities to support the design of the GSE will begin at ATP with the Core requirements review to identify the service resources to be supplied, select design concepts to accomplish the intended function, perform trades and analyses, and select the optimum concept for each piece of GSE required. The activities to perform the selection of the individual GSE is similar to the concept identification and selection for the SSFF Core equipment as defined in sections 5.2.2 and 5.2.3, except that the input information required will be different. The identification and design of all GSE will take into account modularity, when possible, to support the next phase of development, which will allow

savings on development costs. The cost data related to the development of GSE for the SSFF is provided in the DR-5 data submittal.

The SSF resources simulation GSE and the FM loads and interface simulation GSE is required to adequately test the SSFF Core hardware and application software interfaces for proper functional performance during checkout activities through each phase of development, and allowing the incremental identification of design improvements through Flight Unit design activities. The handling GSE will be required to locally transport the Core components and assemblies as well as non-handling GSE within the respective facilities without causing damage to equipment or injury to personnel. The support structure GSE will be required to support the Test Article components or assemblies and the non-structural GSE equipment during the testing, assembly, integration, and/or checkout activities. The special test GSE will be required to test each phase of the SSFF Core hardware and software or non-test item GSE at the component or subsystem level for proper operation at specified environments (e.g., pressure testing of accumulators) as required prior to assembly and integration activities. The special tooling GSE is required to aid in the physical assembly and integration of the Core subsystems and GSE assemblies.

The activity to identify the concepts and select the optimum concept for each category of GSE will require the following input information:

- SSF Resources Simulation GSE
    - Interface definition and capabilities of the of the applicable SSF resources
    - Interface schematics/drawings detailing the SSFFsubsystem-to-SSF resource interfaces
    - Intended facility layout and resources available where the GSE will be required
- FM Loads and Interface Simulation
    - Interface definition and resource usage requirements of the applicable FM interfaces
    - Interface schematics/drawings detailing the SSFF subsystem-to-FM interfaces
    - Intended facility layout and resources available where the GSE will be required

- Handling GSE
    - SSFF Core components lists
    - Non-handling GSE components lists
    - Mass properties of all components, subassemblies, or assemblies that will require handling GSE
    - Parts and assemblies drawings of Core equipment and non-handling GSE
    - Intended facility layout and resources available where the GSE will be required

- Structural Support GSE
    - Core components lists
    - Non-structural GSE components lists
    - Mass properties of all components, subassemblies, or assemblies that will require structural support GSE
    - Parts and assemblies drawings of Core equipment and non-structural GSE
    - Materials lists of all equipment that will require interface with structural support GSE
    - Intended facility layout and resources available where the GSE will be required

- Special Test Apparatus GSE
    - List of equipment to be tested
    - Parts and assemblies drawings of the equipment requiring testing
    - Environments to which the equipment will be required to be designed
    - Materials lists of all equipment to interface with the GSE
    - Intended facility layout and resources available where the GSE will be required

- Special Tooling GSE for the Phased Core Articles' and GSE Assembly and Integration

- Parts and assembly drawings
- Interface schematics/drawings
- Assembly and integration procedures

Following the selection of the optimum concepts for each GSE category the design activities will begin. The design activities for each of the GSE categories defined will include the analyses and preparation of documentation similar to the activities defined for the design of the Core. Differences exist for the analyses and documentation output requirements for the design of each of the GSE in the categories listed. The input information used to identify the concepts for GSE development will also be used for the design reference, and will be supplied through internal sources of the SSFF Core developer. The design output products for the development of the GSE will include the following:

- SSF Resources Simulation GSE Design Output
  - Parts drawings
  - Assembly and integration drawings
  - Materials list
  - Mass properties
  - Thermal analyses
  - Electrical schematics
  - Command and data schematics
  - Facility resource usage identification
- FM Loads and Interfaces Simulation GSE Design Output
  - Parts drawings
  - Assembly and integration drawings
  - Materials list
  - Mass properties
  - Thermal analyses
  - Electrical schematics
  - Command and data schematics
  - Facility resource usage identification
- Handling GSE Design Output
  - Parts drawings

- Assembly and integration drawings
- Materials list
- Mass properties
- Facility resource usage identification

- Support Structure GSE Design Output
  - Parts drawings
  - Assembly and integration drawings
  - Materials list
  - Mass properties
  - Structural analyses
  - Facility resource usage identification

- Special Test Apparatus GSE Design Output
  - Parts drawings
  - Assembly and integration drawings
  - Materials list
  - Mass properties
  - Structural analyses (as required)
  - Thermal analyses (as required)
  - Facility resource usage identification
  - Electrical schematics (as required)

- Special Tooling GSE Design Output
  - Parts drawings
  - Assembly and integration drawings
  - Materials list

A list of representative GSE based on the SSFF Core subsystems identified during the Phase B effort for each of the listed categories is presented in Table 5.2.5.6-1.

TABLE 5.2.5.6-1 REPRESENTATIVE GSE REQUIREMENTS

GSE CATEGORY	GSE ITEM
SSF Resources Simulation	Power Simulator Coolant Simulator Avionics Air Simulator Gaseous Nitrogen Simulator Vacuum Simulator FDDI Simulator HRDL Simulator Video Simulator 1553 Simulator Crew Interface Simulator
Furnace Module Loads and Interface Simulator	Power Simulator Coolant Simulator Gaseous Nitrogen Simulator Argon Simulator Vacuum Simulator Measurement and Control Simulator Video Simulator 1553 Simulator
Handling GSE	As Required
Structural Support GSE	As Required
Special Test Apparatus GSE	As Required
Special Tooling GSE for the Phased Core Articles' and GSE Assembly and Integration	As Required

5.3 CORE TEST ARTICLE DEVELOPMENT

The development of the Test Article hardware and software is required to demonstrate the technological design approach for the SSFF Core Flight Unit, including interface compatibility and equipment functionality. This development and demonstration of the Test Article will assist in reducing the technical, schedule and cost risks involved in providing flight certified SSFF Core equipment.

A review of the subsystem level design concepts and preliminary design approach developed during the Phase B portion of the SSFF contract will be conducted after the contract ATP for evaluation during the time period from ATP-to-PRR. Concepts other than those identified during the Phase B contract effort will also be identified and reviewed for evaluation and selection of a design for the SSFF Core development. The Test Article development will be initiated immediately after the SSFF Core subsystem level concept selection at the beginning of PDR activities.

The Test Article hardware and software will be developed based on the preliminary design analyses and documentation and drawings prepared for input and review at PDR for the SSFF Core Flight Unit. However, the Test Article will utilize commercial grade components to substitute for flight grade components, unless the function of the component will be compromised and not allow an accurate technology and functionality performance assessment, to reduce the costs. For some components the analyses, documentation and drawings being prepared for the Flight Unit as input to the PDR will not apply to the Test Article due to certain aspects of the component. The Test Article components need only to be functionally accurate. For components in which this is applicable, the design analyses, documentation, and drawings being prepared for input to PDR will be modified where possible, as opposed to generating all new design inputs to allow cost savings. Therefore, the Test Article hardware and software development will incur additional activities other than those performed for the Flight Unit during this phase of the SSFF development. These additional activities include engineering analyses, design modification or redesign, manufacturing, procurement, assembly and integration, component and assembly testing, management planning, and functional checkout activities. A description of each of these activities is presented in the following paragraphs.

5.3.1 Engineering Analyses Activities

Engineering analyses activities will include the review of components identified as part of the preliminary design input for the PDR, review of the function of each of these

components, and the selection of substitute commercial components to satisfy these component functions and physical interfaces. The actual selection of the commercial components will involve generating functional block diagrams and schematics of the Test Article subsystem level equipment, researching the capabilities of off-the-shelf equipment including finding the least expensive equipment, identifying components that are not readily available as off-the-shelf equipment that require development or fabrication, identifying components that require the use of flight fidelity hardware or software (as required), and performing cursory analyses to ensure that the Test Article component configuration will suffice with respect to functional performance specification ranges and physical interfaces.

5.3.2 Design Modification / Redesign Activities

Design modification or redesign activities will include performing the actual design modification or redesign analyses of the Flight Unit design input analyses prepared for PDR, and the generation of drawings to support the modification or redesign of components required to make up the Test Article. The drawings preparation will include the generation of component design drawings for components not commercially available as off-the-shelf equipment, modification of drawings being developed as input to the Flight Unit PDR for applicable components, and the generation of assembly and integration drawings. These activities will apply to all classes of hardware and software that require development with the Test Article including all GSE and special test equipment. An estimate of the number of components (parts) drawings and assembly and integration drawings that are required specifically for the Core Test Article may be determined from the Phase B SSFF Core conceptual design effort inputs for each subsystem. The number of drawings to be developed for the Core as analytical integration inputs to each major milestone/review will be addressed in the Flight Unit development paragraph of this section.

5.3.3 Manufacturing and Procurement Activities

Manufacturing activities will include the review of drawings developed through the design modification or redesign activities, development of fabrication plans including the identification of quality inspection points, and the actual fabrication of the components. The manufacturing activities will begin after the PDR and after receiving approval from NASA. The quality assurance activities associated with the fabrication of the Test Article equipment components and support equipment components will be minimal in comparison

to the activities required during the fabrication of Flight Unit equipment to reduce the associated costs. However, the quality activities will include enough involvement to ensure that the Test Article components and support equipment components will be fabricated within the identified design specifications, and thus, protect the time and materials investment to this point in the SSFF Core development.

Procurement activities will include the actual requisition of off-the-shelf equipment identified through the engineering analyses activities previously described for the Test Article development. These activities will involve the evaluation of the required components for functionality and physical interface agreement with respect to the commercial components identification and cursory analyses inputs versus the costs. This includes interfacing with the designers in the event that the commercial component identified is not available or can be replaced with a less expensive component that performs the same function.

5.3.4 Assembly and Integration Activities

Assembly and integration activities will include the assembly of fabricated and procured components into subassemblies or subsystem assemblies for the Test Article and supporting equipment, and the integration of all Test Article subassemblies and/or subsystem assemblies into the supporting structural equipment and into appropriate special test equipment. These activities will overlap with the segmented completion of manufacturing activities for the various components requiring fabrication. These activities more specifically involve the assembly of components into the subsystems that will make up the Test Article, and the subsequent integration of these subsystems into appropriate test sets as required for functionality testing, the integration of the Test Article at the subsystem level into a ground support structure to emulate the rack interface, and the proceeding integration of the Test Article assembly with appropriate test set equipment. The integration and/or interface of Test Article components and subsystem assemblies with test set GSE is required to verify functionality in an evolutionary approach to ensure system operability and integrity during final checkout.

5.3.5 Testing Activities

The testing activities will include performance confirmation testing and safe operation proof testing of the fabricated and procured components, the subsystem level assemblies, and ultimately the Test Article assembly. The identification of appropriate

facilities, whether in-house or subcontractor facilities, to conduct the testing activities will initially be required. These testing activities will require the use of GSE test sets, which will be designed and developed in parallel with the Test Article components, and will take into account the Test Article use environment and available resources. The actual testing activities will initially involve the verification of fabricated and procured items for operation in the worst-case environmental conditions to which the items may be subjected in the Test Article laboratory. This is required to ensure that the items will not cause a safety hazard during checkout activities which might cause injury to personnel or damage to GSE or other Test Article components or assemblies. Testing to verify component operation within designed or advertised specifications in their intended use environments is also required to ensure that successful system functional testing and checkout will be achieved. The general equipment and testing that will be required to verify safe operation will include but not be limited to pressurized equipment testing for maximum expected pressure environments, valve operation testing to ensure that unplanned pressure volumes are not created, heat generating equipment testing to verify touch temperature extremes, electrical circuit overcurrent testing to minimize fire potential, and software control and commanding logic testing for control of equipment that could pose a hazard if not controlled or commanded properly. The general equipment and testing that will be required to verify component critical functions will include but not be limited to thermal equipment (water and air provisions as required) testing for heat rejection of identified heat loads, control and command software testing for validation of command distribution to designated SSFF and FM equipment, and power distribution testing to verify ability to receive power and deliver it to SSFF and FM equipment as required.

5.3.6 Functional Checkout Activities

Functional checkout activities will include the operation of the Test Article system equipment for evaluation of the functional performance of all components planned for use in the Flight Unit design, and the identification of design improvements. The results of these functional checkout activities will be utilized by the SSFF Core and FM developers to proceed with a greater degree of confidence with detailed design activities concerning their respective interfaces, and/or perform design modifications or redesign that may be implemented to increase the reliability and performance characteristics, as well as reduce the maintenance requirements for both on-orbit and periodic refurbishment (performed on the ground) activities. These activities for the SSFF Core Test Article will initially include the operation and monitoring of all subsystems and their components for compliance with

functional performance, design specifications and program requirements. The ensuing activities will include the evaluation of results from the checkout operations, and the determination of the component level design modifications or redesign activities that will ultimately improve the Flight Unit design.

5.3.7 Management Planning Activities

Management planning activities for the SSFF Core Test Article development will include preparation of schedules for the design, fabrication and procurement, testing, assembly and integration, and the functional checkout activities required, the procurement and supervision of facilities and their usage for performing the tasks and activities described, the monitoring of discipline performance for each of the schedules, and the evaluation of discipline performance for improvement and cost reduction. The schedule preparation activities involve reviewing the Test Article development activities requirements as input to the development of an overall Project Master Schedule, and the subsystem level schedules required for the design, fabrication, assembly and integration, testing, and checkout activities. The development of facilities usage schedules for each of the required facilities (i.e., office, fabrication, testing, and assembly and integration and checkout facilities) will also be an activity associated with the schedule preparation for the Test Article. The Test Article activities with respect to overall SSFF development are embedded in the Flight Unit schedule in Figure 5.2-1.

The procurement and supervision of the facilities will involve reviewing the resources required to conduct the described activities, locating and securing the facilities that accommodate these requirements, planning the usage of the facilities as applicable to the development of the Test Article, and controlling and monitoring the activities that take place at each facility. The usage of these facilities will be optimized with respect to availability and activity to save on development costs of the Test Article, and subsequent GCEL and Flight Unit equipment.

The management planning activities of monitoring and evaluating the performance of the engineering disciplines will initially involve the monitoring of actual man-level efforts for design, fabrication and procurement, testing, assembly and integration, and checkout activities for evaluation against the man-level allocations defined in the Phase C/D budget planning for the Test Article with respect to the overall development of the SSFF. The evaluation performance assessment will include manpower, facilities and resource usage versus schedule and cost. The assessment of discipline performance during the Test

Article development will identify critical activities to be streamlined during the remaining development activities for the GCEL and Flight Unit.

5.4 CORE GCEL DEVELOPMENT

The development of the SSFF Core Ground Control Experiment Laboratory (GCEL) hardware and software is required for qualification activities, to provide SSFF Core capabilities and flight identical interfaces as simulation GSE for FM GCEL hardware and software, to perform parallel ground operation of the on-orbit Flight Unit hardware and software, and to perform interface verification of Core ORUs and incremental FM hardware and software that will interface with the SSFF Core on-orbit, in particular the FM 2 hardware and software. The development of the SSFF Core GCEL will also allow ground-based assessment of on-orbit activities prior to and during the SSFF term on-orbit, as well as provide a means for verifying both physically and functionally any ORUs or incremental hardware and software that will interface with SSFF Core centralized and/or distributed equipment.

The ongoing review and assessment of the results and lessons learned from the Test Article development will be administered for the development of the GCEL hardware and software, along with the detailed design analyses and documentation and drawings prepared for input and review at CDR for the SSFF Core Flight Unit. The GCEL development will be initiated after the engineering design analyses are completed during the time period between PDR and CDR, and after the Test Article has been proven and in operation. Waiting until this time to begin GCEL activities will ensure component level functionality of the SSFF Core design, and reduce the associated cost and schedule risks. The parallel GCEL components of those Test Article components that reflect the functional accuracy of the intended flight components, but not the physical interface or flight configuration, will obviously have higher risks for successful development with respect to schedule, cost, and technology than those parallel components that will be developed with functional accuracy and physical interface fidelity during the Test Article development phase. The schedule and cost risks will primarily be associated with additional activities associated with initial safety testing of the component for its use environment and functional checkout for these components before assembly with other components into the appropriate SSFF Core subsystems, and ultimately the integrated SSFF Core.

The GCEL hardware and software will be developed based on the detailed design analyses, documentation, and drawings prepared for input and review at CDR (detailed design review) for the Flight Unit, which will be an update to the preliminary design activities incorporated into the Test Article development. The actual hardware and software for the GCEL development will require incorporation of CDR comments to provide final flight grade physical interface and functionality since the GCEL will be used as a

qualification unit for the Flight Unit, a flight backup unit at the component level (as ORUs), and will eventually be utilized as Core simulator GSE for each FM element GCEL development and for FM 2 interface and functional verification, as well as for interface verification of subsequent FM 1 and FM 2 refurbishments. The Core GCEL hardware and software will require duplication to accomplish the described purposes. The rationale behind duplication of this hardware and software will be detailed in Section 9.0, Logistics. The GCEL hardware and software development fidelity will be in two stages. The first stage will include the incorporation of the detailed design as flight fidelity level component fabrication, procurement, and production to allow accurate qualification testing and to maintain a set of backup equipment for use as ORUs. The second stage will include the incorporation of the detailed design for GSE to support subsequent FM GCEL development, which only requires the functional and physical interface fidelity without the flight qualification configuration control. The GCEL to be used as GSE will be an upgrade of components developed as the Core Test Article to reflect the updated design of the Core at this point in the development. This rationale will allow a reduction in the overall development costs, without compromising the success of the Core development, and ultimately the integrated SSFF development and operation in the USL.

The DDT&E activities associated with the development of the Core GCEL will incur additional activities other than those identified as part of the detailed design phase activities required for the overall development of the Core Flight Unit. These additional activities include engineering analyses, manufacturing, procurement, assembly and integration, component and assembly testing, management planning, and functional checkout activities. A description of each of these activities is presented in the following paragraphs.

5.4.1 Engineering Analyses Activities

Engineering analyses activities will include the review of components identified as the critical (detailed) design input for the Core CDR, review of the function of each of these components in their intended use environment, identification of the components that will require actual physical qualification testing, and providing analyses to the development of qualification test plans.

5.4.2 Manufacturing and Procurement Activities

Manufacturing activities for the Core GCEL development will include the review of the updated drawings developed through the detailed design activities for input into the Core CDR, development of fabrication plans including the identification of quality inspection points, and the actual fabrication of the components. The manufacturing activities will begin after the formal CDR and after receiving approval from the NASA project management to proceed. The quality assurance activities associated with the fabrication of the GCEL equipment components and support equipment components will be critical for the fabrication of the GCEL qualification unit and the GCEL flight backup unit equipment, and will be less critical for the GCEL equipment to be used as GSE for FM development activities. The criticality of quality involvement for the GCEL qualification and flight backup is obvious due to the functions that each of these pieces of equipment will perform in the SSFF Flight Unit development and maintenance. The rationale for providing each of the GCEL units is detailed in section 9.0, Logistics, of this document.

Procurement activities will include the research and selection of acceptable equipment and/or equipment subcontractors to accomplish the fabrication, assembly, and testing of components identified through the critical design input of the Core developer identified through the engineering analyses activities previously described. This will apply to components that cannot be fabricated by the Core developer, or to components that can be developed and qualification tested by subcontractors at a lesser development cost to the program. The components that require procurement versus in-house fabrication will require identification as soon as possible so that the if long lead times are required, the initiation of subcontractor activities to provide the components will be initiated in time to support the Core and overall development and integration schedules.

5.4.3 Assembly and Integration

Assembly and integration activities will include the assembly of fabricated and procured components into subassemblies or subsystem assemblies for the Core GCEL and supporting equipment, and the integration of all Core GCEL subassemblies and/or subsystem assemblies into the supporting structural equipment and into appropriate special test equipment. These activities will overlap with the segmented completion of manufacturing activities for the various components requiring fabrication. These activities more specifically involve the assembly of components into the subsystems that will make up the Core GCEL as well as the Flight Unit for the Core eventually, and the subsequent

integration of these subsystems into appropriate test sets as required for functionality testing, the integration of the GCEL at the subsystem level into a ground support structure to emulate the rack interface, and the proceeding integration of the GCEL assembly with appropriate test set equipment. The integration and/or interface of GCEL components and subsystem assemblies with test set GSE is required to verify functionality in an evolutionary approach to ensure system operability and integrity during final checkout.

5.4.4 Testing Activities

The testing activities will include performance confirmation and safe operation proof testing of the fabricated and procured components, the subsystem level assemblies, and ultimately the qualification testing of the GCEL assembly. The qualification testing activities will be performed on the GCEL to provide acceptance for the Core Flight Unit. The rationale for use of a GCEL unit for qualification testing instead of the Flight Unit is to reduce the cost impact risks of not meeting flight schedules due to a potential anomaly of the Flight Unit during qualification efforts, versus the production costs of additional equipment (i.e., an additional GCEL) and analyses to prove acceptability. All testing associated with the GCEL development will initiate with the identification of appropriate facilities, whether in-house or subcontractor facilities, to conduct the testing activities. The testing activities will require the use of GSE test sets, which will be designed and developed as upgrades to the GSE developed for the Test Article components checkout, and will take into account the Flight Unit use environment for the testing criteria and will involve the verification of fabricated and procured items for operation in the worst-case environmental conditions to which the items may be subjected both on-orbit and in the ground laboratory. This is required to ensure that the items will not cause a safety hazard during checkout activities which might cause injury to personnel or damage to GSE or other GCEL components or assemblies. Testing to qualify components within designed or advertised specifications in their intended use environments is also required to ensure that successful system design is achieved prior to integration and flight of the SSFF Core. The general equipment and testing that will be required to verify safe operation in the laboratory will include but not be limited to pressurized equipment testing for maximum expected pressure environments, operation testing of all components and subassemblies in worst-case use environments on the ground, heat generating equipment testing to verify touch temperature extremes, electrical circuit overcurrent testing to minimize fire potential, and software control and commanding logic testing for control of equipment that could pose a hazard in the laboratory if not controlled or commanded properly. The qualification testing

of the GCEL will be performed as required to prove acceptability with respect to CEI specifications requirements of the Core, and verify performance of the Core components and subassemblies.

5.4.5 Functional Checkout Activities

Functional checkout activities will include the operation of the GCEL system equipment for evaluation of the functional performance of all components planned for use in the Flight Unit design, and for use as a GSE simulator for FM development. These activities for the SSFF Core GCEL will include the operation and monitoring of all subsystems and their components for compliance with functional performance, design specifications, and program requirements for acceptance of the Flight Unit design. The completion of these activities will prove the Flight Unit design, and allow for continuation with Flight Unit final design, fabrication/procurement, assembly and integration, and the final checkout during acceptance demonstration testing at the Core CAR and ultimately at the IPL-CAR with the FM Flight Unit equipment. Also, the completion of these activities will allow the FM developers a high-confidence Core interface simulator as GSE to complete their respective design, qualification, and checkout activities.

5.4.6 Management Planning Activities

Management planning activities for the SSFF Core GCEL development will include preparation of schedules for the design, fabrication and procurement, testing, assembly and integration, and the functional checkout activities required, the procurement and supervision of facilities and their usage for performing the tasks and activities described, the monitoring of discipline performance for each of the schedules, and the evaluation of discipline performance for improvement and cost reduction. The schedule preparation activities involve reviewing the GCEL development activities requirements as input to the development of an overall Project Master Schedule, and the inputs into the subsystem level schedules required for the design, fabrication, assembly and integration, qualification and component performance operations testing, and checkout activities. The development of facilities usage schedules for this phase of the Core development will also be an activity associated with the schedule preparation for the GCEL. The schedules depicting the GCEL activities described with respect to overall SSFF development, and at more detailed subsystem level development and applicable facilities usage are presented in Figure 5.1.2-1.

The procurement and supervision of the facilities will involve reviewing the resources required to conduct the described activities, locating and securing the facilities that accommodate these requirements, planning the usage of the facilities as applicable to the development of the GCEL, and controlling and monitoring the activities that take place at each facility. The usage of these facilities will be optimized with respect to availability and activity to save on development costs of the Test Article, and subsequent GCEL and Flight Unit equipment.

The management planning activities of monitoring and evaluating the performance of the engineering disciplines will initially involve the monitoring of actual man-level efforts for design, fabrication and procurement, testing, assembly and integration, and checkout activities for evaluation against the man-level allocations defined in the Phase C/D budget planning for the GCEL with respect to the overall development of the SSFF. The evaluation performance assessment will include manpower, facilities and resource usage versus schedule and cost.

5.5 TRAINING SIMULATOR (TRAINER) DEVELOPMENT

The development of SSFF Core training simulators will require close work with the training function to produce the necessary hardware and software to accommodate the crew training activities. The training function will develop the necessary documentation (PTRDs Part I and Part II reflecting evolving training fidelities - see section 7.4) to define the trainer requirements. The DDT&E activities to produce the trainers will include reviewing the PTRD inputs from the training function, performing the design analyses to implement the trainer requirements, manufacturing and procurement of materials and equipment to produce the trainer hardware and software, and assembly and checkout of the trainer hardware and software. Management planning activities, similar to those described for the other development items will also be required, as well as sustaining engineering to support the training function activities.

The activities to review the PTRD inputs and perform design analyses will include the identification of parts/components to satisfy the trainer requirements described in the respective parts of the PTRD, the preparation of parts and assembly drawings, the identification of commercial equipment components to provide the required crew or flight interface, and the assessment of the fidelity of the commercial components. These activities will produce the necessary drawings and materials identification to manufacture and/or procure the trainer hardware and software.

The manufacturing and procurement activities will involve reviewing the drawings and documentation provided as a result of the PTRD review and design analyses activities, developing the fabrication plans, identifying the necessary quality inspection points, researching commercially available equipment and/or subcontractors, performing the actual fabrication and purchase of the required components, and receiving, inspecting, and maintaining inventory on all of the items. These activities will be required to allow the assembly and checkout of the trainers for use by the training function.

The assembly and checkout of the trainers will involve assembly of the components into appropriate subsystems, integration of the subsystems into appropriate test sets and support facilities, testing the subsystems for required functionality per the PTRD, integrating the subsystems into the trainer system assembly, and performing the final system level checkout for use in the training exercises as described in section 7.0.

The management planning activities will include the development of schedules to reflect the trainer development activities described in the previous paragraphs, the development of facilities usage schedules for facilities required to support the production of the trainers, and the monitoring and evaluation of the trainer development tasks and the respective discipline personnel involved in these activities. These activities are typical of the management activities described for the Flight Unit, Test Article, and GCEL developments.

The sustaining engineering activities will involve reviewing the performance of the required trainers during each phase of the training exercises, and general support to the training function during each phase of the training exercises. These activities will include evaluating the trainer performance at the component level to determine improvements, as required, for the next phase/fidelity of training as described in section 7.0, and will include explanation of the operation and function of each trainer at the component and subsystem level to the training function and/or other functions as required.

5.6 FURNACE MODULE DDT&E

The activities required to perform the DDT&E function activities for the FM 1 and FM 2 elements are similar to the Core DDT&E function activities described previously in sections 5.0 through 5.4 of this document. The development of the FMs will require the same primary activities (such as requirements review, design analyses, manufacturing and procurement, assembly integration and checkout, etc.) and interrelationships between the discipline functions as for the Core including the analytical integration, physical integration, training, operations, and logistics. The development of each FM will also require an evolution from Test Article to Flight Unit with the GCEL Unit being used for qualification. The primary difference between the Core DDT&E function and the FM DDT&E function will be governed by the nature of the design requirements, and the subsequent testing requirements and support engineering requirements. The FM developers will need to establish and maintain a close working relationship with the PIs to ensure the receipt of mature and valid FM design capabilities requirements to support the required science objectives.

The schedules providing an overview of the major FM 1 and FM 2 activities, respectively, during the course of development of FM hardware and software, ground activities, and flight activities are presented in Figure 5.2-2 and 5.2-3, respectively, as previously identified. Reference to schedule 5.2-1, Core Flight Unit Development, will be required to determine activities detail.

6.0 INTEGRATION

The integration portion of the SSFF development is separated into Analytical Integration and Physical Integration. The analytical integration activities will be performed during both the development of the SSFF and during its utilization, and will involve the major tasks of definition of interfaces, review of element level assembly and integration designs for compliance with element-to-element interface agreements and element-to-SSF interface agreements, development and control of interface documentation, verification and safety identification and definition, verification plan development and maintenance, and the tracking and review of the safety and verification. The physical integration activities will be performed during the development of the SSFF and during its utilization, and will involve the major tasks of performing assembly of SSFF elements at the subsystem level, integration of the elements with each other (including into the Core-developed flight rack structures), actual physical interface verification testing and checkout, and the post landing de-integration of the SSFF in particular with respect to resupply items during the life of the SSFF on-orbit in the USL. The analytical and physical integration activities for the SSFF is presented in the following paragraphs.

6.1 ANALYTICAL INTEGRATION

The analytical integration activities will include developing the engineering definition of interfaces for each SSFF element for use or interface by another SSFF element, documentation of the interface definitions by means of interface control documents between each element developer and between each element developer and the SSFP, maintaining the interface definitions and subsequent documentation as each element and the SSF interface designs mature, providing verification definitions as applicable to each elements' operation and interface both prior to launch and on-orbit, preparing verification planning documentation the SSFF elements and the integrated payload of each flight increment, tracking the verification analyses, test, and inspection reports for acceptance and closure, performing safety analyses, preparing safety documentation to support the safety reviews, and providing the necessary review support for the major milestones/reviews of each SSFF element. The overview schedule of typical analytical integration task functions is presented in Figure 6.1-1.

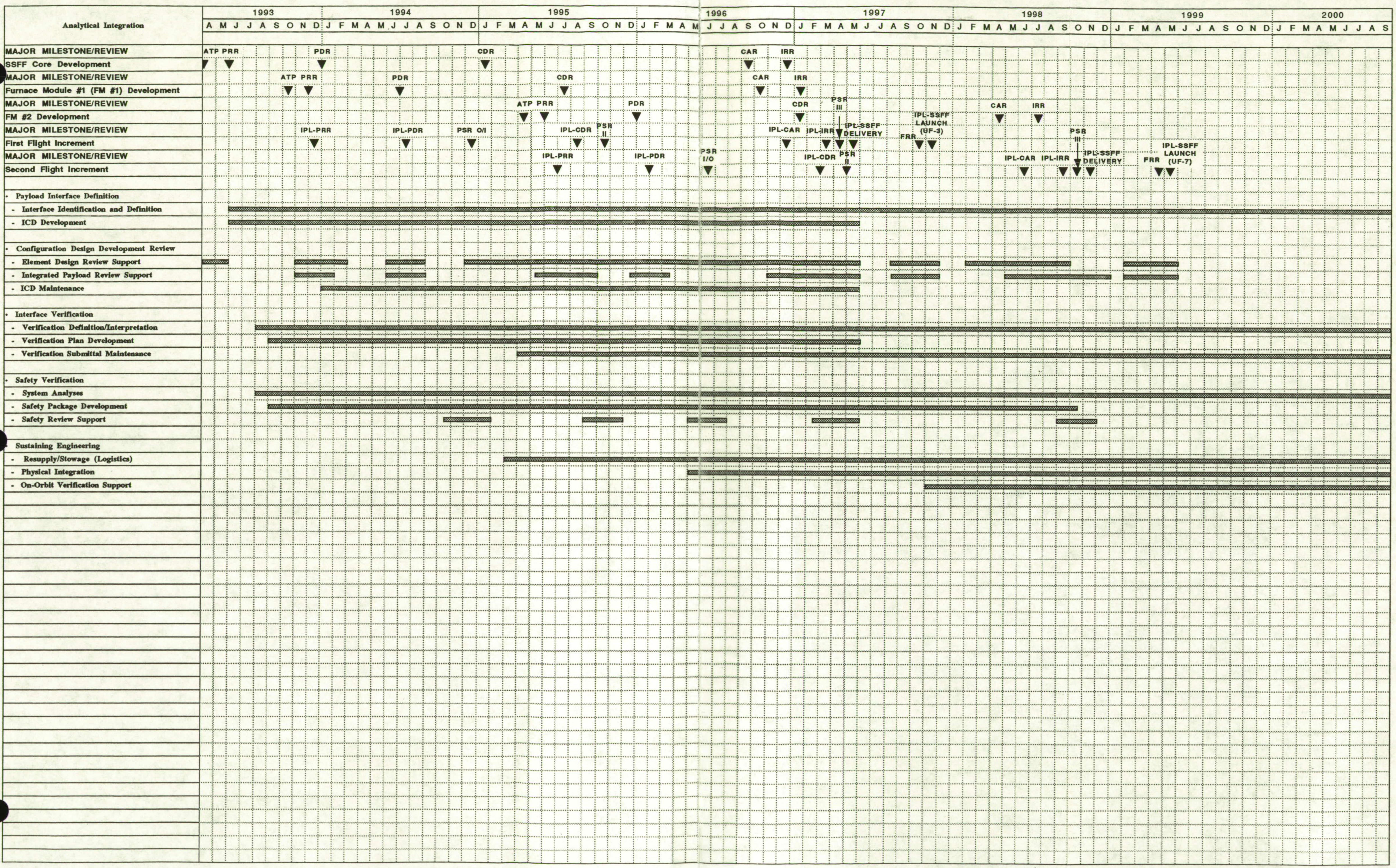


FIGURE 6.1-1 ANALYTICAL INTEGRATION ACTIVITIES SCHEDULE

FOLDOUT FRAME 1

FOLDOUT FRAME 2

6.1.1 Payload Interface Definition

The definition of engineering interfaces for each element will require mutual inputs from each developer and the SSFP. These interfaces include the Core-to-FM interfaces (rack/rack), Core-to-SSF (payload/USLab), and integrated SSFF-to-Carrier (payload/Logistics module) for each flight increment. The interface definitions for the Core-to-FM interfaces will be accomplished by consolidating the interface requirements from the preliminary requirements reviews between each element, incorporating design activities as the designs for each element matures (iterative process) to ensure compatibility on each side of the interface, documenting the interfaces through this iterative process to make appropriate adjustments as the designs for each element matures, and reviewing and approving the design and performance specifications of each element to ensure compliance with documented interface agreements. The documentation of the interface agreements will performed by means of Interface Control Documents (ICDs). These activities will be difficult for the integrated payload of the first flight increment, due to the staggered schedule ATPs (~six months difference). The ICD development for this situation will have to be premised on the Core interface design and the FM interface requirements until the preliminary design for the FMs is initiated.

Similarly, the ICD development for the Core-to-SSF can be physically defined with respect to rack interfaces at the utility interface panel located in the rack structure, but not functionally with respect to allocations until the FM requirements are substantiated by design activities. The ICD for defining and controlling the integrated payload-to-Logistics module interfaces will progress with the Core design, since the Logistics module interface will be defined by ATP of the Core development contract.

6.1.2 Configuration Design Development Review

The activity to review and approve the design and performance specification of each element for each ICD will include obtaining and reviewing all design documentation (especially Assembly and Integration drawings) and attending the corresponding design reviews, maintaining routine communication between each of the element design organizations, and providing discrepancy comments on the design reviews. The maintenance of the ICDs will also be performed by the analytical integration function. The ICD maintenance activity will involve changing the ICDs in step with approved iterative design changes that affect the physical interfaces or functional allocations available. This

includes understanding the rationale for the interface changes, the timely submittal of changes for review by the configuration control board for the ICDs, the preparation and presentation of the changes and rationale material to the configuration control board for approval, implementing the approved changes in the ICD, and distributing the update for review by each affected party.

6.1.3 Interface and Safety Verification

The analytical integration function will be responsible for identifying and defining interface and safety verification applicability to each element both prior to launch and on-orbit, prepare the verification planning documentation for each element and the integrated payloads for each flight increment, process and track verification data submittals (analyses reports, test reports, and inspection reports) from the respective DDT&E functions, and archiving the data submittals for future reference. The activities required to perform the identification and definition of the interface and safety applicability to each element of the SSFF prior to launch will include obtaining and reviewing the SSFP Payload Verification Program Plan and the IROP, arranging and attending meetings with the SSFP to understand the definition of each verification requirement listed in the IROP and how these requirements apply to individual payloads, and presenting unique interface and safety requirements scenarios to the SSFP for interpretation of applicability to verification. The on-orbit aspects of this activity include interfacing with the SSFP to determine the technical requirements for on-orbit interface verification including procedures and functional tests requirements prior to activation of the hardware. Also, the on-orbit verification definition activity will include coordinating unique payload proposals from the DDT&E function of each element to accommodate the on-orbit verification acceptability. This will involve arranging and attending meetings with the SSFP and maintaining routine communication with the responsible SSFP organization concerning potential interface and equipment anomalies for each payload, documenting the accepted agreements, and interpreting this information to the other functions (i.e., DDT&E, physical integration, mission operations, and training). The number of meetings to be held for verification definition prior to launch and on-orbit will be dependent on the interface design of the payload, and how many verification requirements are applicable to the particular payload. Based on previous Spacelab experience, approximately 50 % - 75% of all verification requirements listed in the IROP that are applicable to a payload element the size of the Core and FMs will need interpretation for the method of certification.

The preparation of the verification planning documentation will require the analytical integration function to understand each of the SSFF elements interfaces, and the function of each of the components that make-up the element and the elements' supporting equipment (GSE). This will be accomplished by maintaining a working relationship with the DDT&E function of each element developer through scheduled meetings and routine communication. These meetings and communication mechanisms will coincide with the necessary meetings for the development of the ICDs previously discussed. The attendance of the major design reviews for each element, and the review of all drawings, operating procedures, structural analyses, thermal analyses, electrical schematics, MIULs and MUAs, mass properties reports and the software requirements and implementation inputs provided by the DDT&E function of each element will be a required activity of the analytical integration function. Typically, integration contractors require dedicated engineering support to accomplish this task for each ICD and Verification Plan development, tracking, and maintenance for each major element (i.e., the Core, FM 1, and FM 2). The maintenance of the verification plans will require similar activities as defined for the ICDs.

The analyses, tracking, and archiving of verification submittals will be performed by the analytical integration function. The verification submittals, either by analyses, tests, or inspections data, or combinations of these data, will be provided to the analytical integration function by the DDT&E function of each payload element for acceptability review and analyses for each applicable verification requirement item. The review and analyses will involve checking the data submittals for content quality with respect to the intended verification requirements, and determining acceptability for reciprocal submittal to the SSFP integration organization. The tracking of the data submittals to determine the status of acceptability to determine if additional data is required before closure of the particular item both internal to the element developer and with the SSFP integrations organization will be required. It will involve periodic communication with the data analyzers of the respective organizations. The periodic communication will be based on when the data is submitted and required for each item, and may occur weekly at first, and then daily as the status of the item becomes critical to the schedule. The verification tracking will require the development of a database to track the whereabouts and status of any standard verification requirement for specific payload applications. The archiving of the verification data will require maintaining the database developed for tracking the verification items, and maintaining hardcopies of the data submittals in a documentation control and storage area. The documentation control and storage area will also maintain a

separate database and microfiche station to accommodate the volume of data as the program matures over the lifetime of the SSFF.

The activity to prepare the composite system analyses and the supporting documentation for the phased safety data packages for flight operations and ground operations for the SSFF elements and GSE will require obtaining and reviewing the applicable program safety documentation and DDT&E inputs for each major design review for each of the SSFF elements at the component level, understanding the functions of each component as an integral part of each design, the integrated payload interface identification and functional descriptions, the SSFF Core FOs, the FM FOs, the interface configuration layout of each element and the integrated payload, the MIUL for the Core and FM equipment, the electrical schematics of the electrical equipment, all specifications of equipment planned to be vendor-supplied, and a description of the software to be utilized. Attending each of the major design reviews, as well as arranging and attending independent meetings and telecons with each element developer, and routine communication will be required to obtain the data inputs. Analyses of these data inputs will be required to ascertain the potential hazard causes, the mechanisms to control the hazards, and identification of verification methods as required, respectively, for each evolutionary phase of the safety process.

6.1.4 Sustaining Engineering

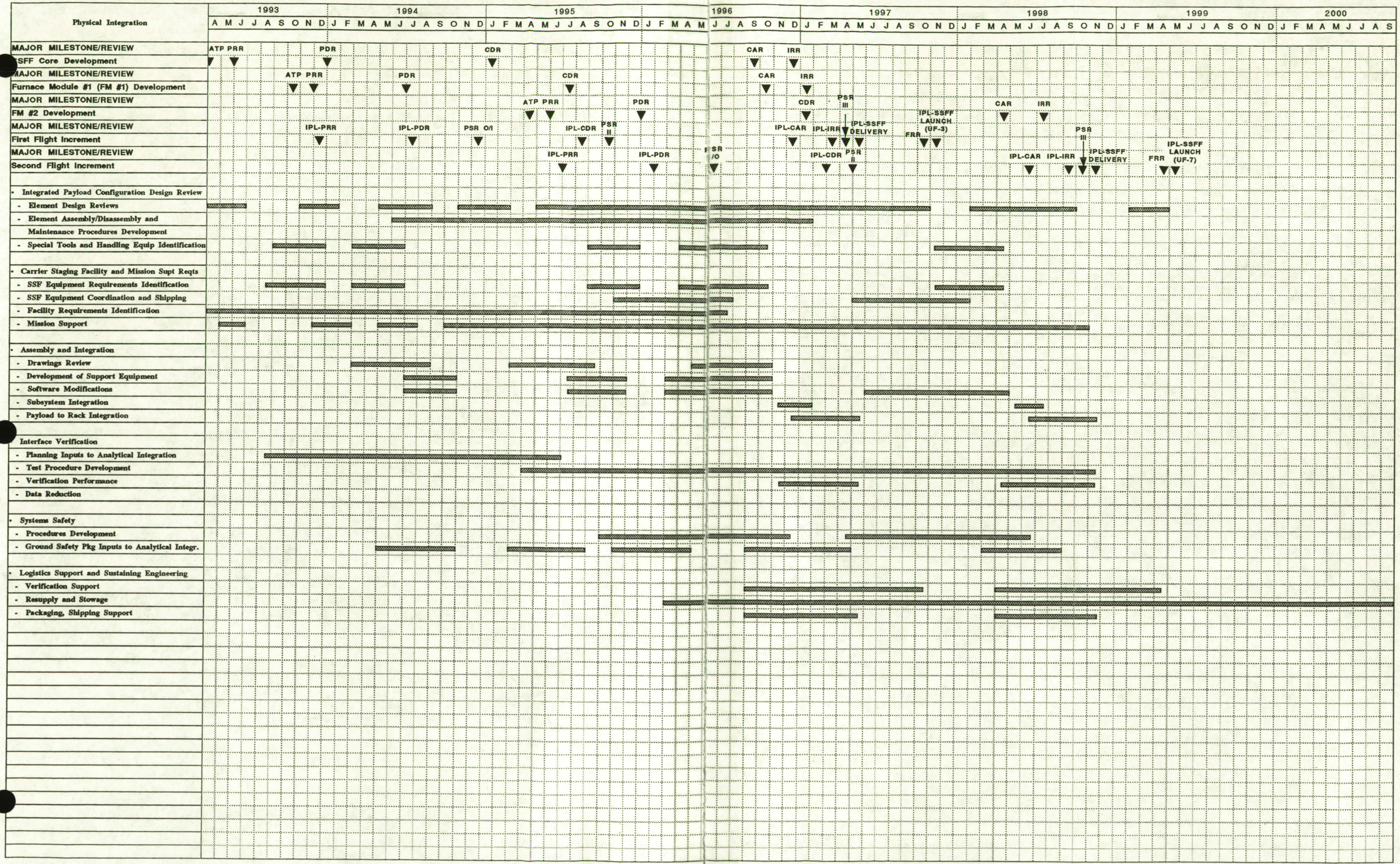
The analytical integration function will also provide input to the logistics function with respect to the resupply/stowage requirements of all SSFF elements for the integrated payload of each flight increment based on the interface control and safety expertise acquired during the SSFF development process. The resupply/stowage requirements for each of elements of the SSFF will be defined during the design process by the DDT&E function of each element, and negotiated in the ICDs by the analytical integration function with the SSFP. The knowledge obtained by the analytical integrator between each elements requirements versus the allocations available from the SSFP, either through logistics module stowage support (available every 90 days) or by stowage on-orbit of the necessary supplies to accommodate the SSFF operation for a given extended period of time, will be crucial to the logistics planning execution.

The analytical integration function will also provide sustaining engineering support during the preparation of physical integration procedures by the physical integration function, during the training of the flight and ground crews by the training function, and during the on-orbit installation and interface verification communicated through the mission

operations function for each flight increment of the integrated SSFF payloads. These activities will include the interpretation of interface design and configuration of the integrated SSFF payloads for supporting the physical integration function, providing input on component, subsystem , and system level operations and response to the training function, and providing interpretation of interface requirements acceptability for physical integration on the ground and for mission operations on-orbit.

6.2 PHYSICAL INTEGRATION

Physical integration involves the functional testing, checkout, installation and verification of the Space Station Furnace Facility (SSFF). Physical integration of the SSFF is a major segment of the SSFF program comprised of all the activities associated with installing the SSFF elements into flight rack structures provided by the Core developer, and the testing and checkout required to complete verification of the SSFF interfaces including control of safety hazards. This effort includes identification and review of the integration requirements design and definition of the flight configuration, preparing the assembly and installation procedures, testing and verification of interfaces, safety hazard control and stowage/spares integration. These activities must be closely coordinated by the physical integration function with the final design and development team of each of the SSFF elements. In many cases the requirements for integration will have the largest impact on the hardware design and consequently the definition of the physical integration requirements will begin at the PDR. The involvement of physical integration at this point will facilitate prevention of major problems prior to the start of hardware fabrication. Physical integration relies upon the DDT&E effort and the analytical integration effort to provide detailed design information on each of the SSFF elements. The level of detail required for physical integration should will include complete information for the development of tests and verification requirements to satisfy all SSF program requirements. The pre-integration and physical interface verification of the SSFF elements into the rack structures for each flight increment will be conducted by the physical integration function to reduce the risks of functional failure, structural misalignment, and subsystem component damage to the SSFF elements due to the repeated integration/de-integration activities usually associated with flight hardware development and subsequent checkout, acceptance, and verification activities. A typical schedule of the physical integration activities is presented in Figure 6.2-1.



FOLDOUT FRAME 1.

FIGURE 6.2-1 PHYSICAL INTEGRATION ACTIVITIES SCHEDULE

FOLDOUT FRAME 2.

6.2.1 Integrated Payload Configuration Design Review

The integrated configuration design and definition for each flight increment will be determined by the module designs, the element designs, and the acceptance of the analytical integration function and will be supplied to the physical integrator function. The physical integrator will use the information supplied for the overall planning and completion of the integration process. The types of information supplied will include assembly and installation drawings, part drawings, and assembly and installation plans/procedures. The drawings will be supplied with procedural detail such as torque loads on bolts, fittings, connectors, and specifications or limits on members under stress and/or bending.

Assembly and installation (A&I) drawings will be developed by the DDT&E function for each SSFF element, and supplied to the physical integration function for physical integration planning. The physical integration function will use the supplied information to develop assembly or disassembly and maintenance procedures. The A & I drawings will be used to verify the SSFF rack and component configuration prior to the beginning of physical integration for each flight increment. The drawings will also be used to identify special tools and equipment to perform the physical integration, which will be provided back to the DDT&E function to procure and/or fabricate the special tools GSE.

6.2.2 Carrier Staging, Facility, and Mission Support Requirements

Carrier staging requirements will be determined by the increment schedules and availability of SSF rack hardware. SSF equipment to be used in the SSFF-supplied rack will be verified by the physical integration function using SSF component drawings and the SSF supplied A & I drawings. Staging requirements will be coordinated with the SSF program for rack staging equipment. SSF program equipment includes Remote Power Control Modules (RPCM), avionics air ducts and diffusers, and fire detection and suppression (FDS) equipment. The Core physical integrator will be responsible for coordinating the shipment and handling of the SSF program hardware being supplied to their facilities, and will supply the necessary storage space and control for SSF-supplied equipment prior to installation and staging.

The physical integration function will determine the amount of facility space required (including storage) and provide the areas needed to perform the SSFF physical integration for each flight increment. The facility resources required include environmental control, power supplies, office space, assembly areas and meeting rooms.

The physical integration function also includes the activity of tracking hardware and inventories, preparing integration schedules, preparing integration documentation and discrepancy and waiver reporting. These activities will require the use of existing software or the development of unique software to aid in their completion.

6.2.3 Assembly and Integration

The assembly and installation effort of the physical integration function will consist of the activities required to install the SSFF Core and FMs into the rack structure and interface each of the elements as required. The assembly of each FM into its rack structure will be performed by the Core developer with support from the FM developer for each flight increment, and will be performed at the MSFC Core developer integration site. The FM equipment will primarily be interfaced to distributed Core equipment in the ER structure. The provision of assembly drawings and wiring diagrams necessary to perform the physical integration tasks will come from each developer's DDT&E functions, with the Core developer providing the larger number of drawings due to the number of individual components associated with its development. This activity requires review of the assembly and installation drawings for the Core rack and ER locations, review of the rack integration requirements, development of adapters, connectors, and shims required for mounting the hardware into the rack structures, and development or modification of the software interfaces to allow the provision of debugging during the physical and functional interface checkout activities. The development of these minor hardware and software interfaces cannot be predicted due to the differences in the interface fidelity during the physical integration versus the fidelity at hardware development. This activity also includes subsystems integration, and the actual payload to rack installation, which will be described in the following paragraphs.

Prior to the individual element integration, each element subsystem must be assembled and verified before installation into the rack structures. Each subsystem will be assembled and independently checked using the assembly and installation drawings and the developed test procedures. Any discrepancies resulting from the subsystems testing will be resolved including minor modifications discussed earlier before proceeding to the next step of the integration process. Once all discrepancies and subsystems testing is resolved full

rack integration will continue with subsystem-to-subsystem integration, and subsystem-to-complement element integration.

6.2.4 Interface Test Verification

The interface test verification activity consists of all the planning and test procedure development, testing, and data analysis required to verify the integrity of the interfaces between the Core and FMs and between the SSFF elements and the SSF. These tests include power, data, thermal, electrical, and operational as defined in the verification plan developed by analytical integration function. The verification plan will define the testing requirements and identify the applicable standards and specifications to be demonstrated during the physical integration. These tests will be performed after the payload elements have been installed into the racks in the flight configuration using the SSF resource interface simulators provided by the Core developer or provided from the SSFP (i.e., WP01 Suitcase Emulator). Interface testing is performed after equipment installation or as specified by the verification plan provided by the analytical integrator. All interface testing and verification will be completed prior to transfer of the pre-integrated payload to the checkout facility at KSC for on-line testing. These activities occur typically 9-11 months prior to flight.

Interface verification will define the required documentation procedures, test report formats, etc. required in the verification plan supplied by analytical integration. The reports will include method descriptions, established definitions, environment criteria and measurement reports of essential engineering data for SSFF verification. This function will establish the basic requirements and recommend methods and techniques to be used in the verification of the SSFF interfaces when mated with the SSF. Coordination with the SSF program will be required to ensure verification of the SSFF meets the programs requirements.

Test data will be reduced and evaluated and test failures will be assessed and modifications to the design or configuration of the payload will be considered. After all tests are passed and data is compiled into reports, the test reports will be included as part of the Flight Readiness Review Data Package. A final payload verification analysis report will be developed which demonstrates the as-built payload compliance with the SSF program requirements.

6.2.5 Systems Safety

Safety test verification will be performed to satisfy the requirements of the payload objectives and to ensure compliance with the strategic, tactical and executive levels of integration of the Space Station Freedom program. Each element of the SSFF will complete the requirements of the CAR and the IRR prior to physical integration with the other elements and the SSF carrier, respectively. Safety and safe operations will be critical to a timely and successful completion of the physical integration process. This will require the development of safety regulations and procedures for all hazardous operations in the integration process. A safety verification plan will be developed to establish hazard procedures and methods of reducing hazards will be implemented for the integration process. The safety requirements plan will be developed for guidance in reducing injuries, preventing damage to facilities and property, and reducing failures.

Systems safety and industrial safety will also be included in the safety plan. Systems safety includes the safe operation and integration of the SSFF payload with the racks. This element also includes the development of safety verification items for reporting to the SSFP. Groups developing verification items may include the physical integration function of each element, ground operations and KSC personnel, as well as the flight crew. Industrial safety includes all procedures to be performed at the MSFC Core developer facility which may affect the safety of physical integration function personnel, the element developers personnel, or any other personnel involved in the physical integration process.

Safety test and procedures will set forth basic elements and techniques for verification of system safety and identification of hazards in the physical integration process. A safety analysis will be performed to evaluate hazards of all tests and procedures. In addition a risk management report based on hazards identified will be developed for avoiding injury. The physical integration function of each element will participate with the analytical integration function and the DDT&E function to develop the flight and ground safety data packages.

6.2.6 Logistics Support and Sustaining Engineering

The logistics support effort also to be performed by the physical integration function will include the coordination of the receipt, storage, and resource supply of SSF hardware and software items, and FM hardware and software items.

Sustaining engineering work will include several areas of the payload development and integration. Prior to physical integration, familiarization with the payload by project

and systems level personnel, will be performed. Another area will include Space Station program safety and integrated payload review cycle participation. Significant levels of sustaining engineering must be maintained during the physical integration process to accommodate technical problems identified during test and verification activity. Past experience indicates that the integrated system performance in terms of EMI and acoustics can deviate significantly from the predicted levels and a design team must be maintained to troubleshoot and correct these problems. The problems corrected will be worked with the DDT&E and analytical integration functions, as well as the NASA engineering and test labs to resolve any discrepancies on drawings, interface schematics, materials lists, assembly & installation drawings, analysis reports, and safety data packages. These types of problems will be anticipated and minimized where possible, but will not be totally eliminated. Inputs and development information for PIA Annex 7 will be developed, which describe the SSFF requirements for physical integration of the pre-integrated payload for each flight increment into the Logistics module at KSC. Finally, after the payload is integrated and shipped to KSC, engineering support at KSC will be required in the event of anomalies occurring during shipping or functional testing and checkout.

Stowage and resupply activities include the activities required for the returning of samples to or from a furnace on-orbit. The activities include the integration and verification of containers and samples to Space Station specifications and the processing required to handle the containers and samples for distribution. The stowage and resupply containers will complete Certification and Acceptance Review prior to physical integration with the SSF carrier. There are three major areas in stowage and resupply: (1) Packaging and Assembly, (2) Increment Processing and Integration and (3) Increment De-integration.

Packaging includes all the functions included in integration of a furnace, or the Core, for further flight increments. The exchange and return of samples for experimentation on orbit will be the primary goal of this function. All safety, verification and integration functions will apply to this element. As with module integration any discrepancies will be coordinated back to the analytical integration function for disposition.

Assembly will include the integration of the container, and the associated samples, for flight up to the already functioning furnace module. All integration functions, for the resupply effort, will be repeatable for the continued use of existing furnace modules. Provisions must also be made for the loading, and return, of the previously processed samples to experiment teams.

The resupply/stowage function will be performed for each payload increment as required by the experiment teams with provisions for a limited amount of resupply

capability available to the experiment teams. Each increment will be limited by the other payload complements being lifted for that flight.

At the end of a resupply effort the recovered samples will be packaged and shipped to the appropriate experiment teams for further study. Reports on the condition of the processed samples will be generated as part of this function and supplied to the SSF program and the appropriate experiment teams. Lessons learned from the resupply effort will be incorporated into the resupply containers' design for future flights. Crew notes and comments will be used to improve the resupply procedures.

7.0 TRAINING

The Training effort shall provide the manpower and associated services required to support and accomplish training of the Crew, POIC Cadre, PIs, and Payload Element Developers (PEDs) to conduct experiment operations for the SSFF during Man-tended and Ground-tended phases of the Space Station Freedom operations. This effort includes planning and documentation of training requirements for SSFF at the PED site, MSFC's Payload Training Center (PTC), and between NASA centers; negotiation of the agreement between the SSFF project and SSFP concerning training; development of the materials required to support the training of the Instructors, Crew, POIC Cadre, and PI/PEDs on SSFF operations; preparation and verification of the SSFF experiment trainers to support training activities; support to the PTC in the development and conduct of SSFP provided training; validation of all training developed by the SSFF project; and execution of the actual training at the PI/PED site(s). The training activities can be broken down to include the assessment of training that needs to be performed for each element and as an integrated payload, the provision of inputs to complete the documentation requirements as defined by the IROP, preparation of documentation to plan the training for each element, to define the trainers (simulators) that need to be developed for each element, to negotiate and agree on the training that needs to be performed between each SSFF element and between the SSFF elements and the SSFP, perform the training preparation tasks prior to beginning the actual training, conducting the actual training exercises, attend SSFP training exercises, and support meetings and reviews as required for each SSFF element.

7.1 TRAINING ASSESSMENT

The training assessment activity obtains experts from the PTC, PI/PED team, and SSFP training together to form a Training Assessment Team (TAT) to discuss and evaluate details on the types of training required, the training sites, the quantity and fidelity of trainers that are needed, and schedules for implementing this training. Typically, this is a series of three to four meetings over a six-month period of time, with each meeting providing more specific information. The PI/PED team will be prepared to attend these meetings having previously reviewed the training requirements and having a basic idea of the activities necessary to train the Crew and POIC cadre on SSFF. A review of SSFP documentation concerning training prior to this time will be performed for familiarization with the processes and requirements for SSF USL training. The information that comes out of the TAT meetings will be used to generate the initial inputs into the IROP and will

serve as a starting point in the development of the User Payload Training Plan (UPTP). This process will be repeated for each increment the SSFF stays on-orbit in the USL, and any major changes to the SSFF will result in additional training activities.

7.2 IROP INPUT DEVELOPMENT

The provision of training inputs to satisfy the documentation requirements of the IROP is the effort associated with completing the initial and subsequent inputs including defining crew and ground support personnel training required to meet operational requirements, location of the required training, and training simulation hardware and software requirements to be accomplished by the end of each of the SSFF elements' PRR. An updated input will include a preliminary training plan that contains a description of the proposed training, a definition of the type of training (workbook, classroom, simulation, etc), location of the training, and simulation hardware/software and interface requirements to be accomplished by the end of each of the SSFF elements' PDR. Another update to all the items described above is required by the end of each SSFF elements' CDR. A final update to the IROP is required for the CAR of each payload element on the SSFF.

7.3 USER PAYLOAD TRAINING PLAN (UPTP) DEVELOPMENT

The preparation of documentation to plan the training for each element will include the analysis of planned experiment operations (Functional Objectives, PI inputs, experiment characteristics, etc..) by study of appropriate documents and participation in the TAT meetings and other activities in order to determine training requirements for the Crew, POIC Cadre, and PI/PED team members. The document to be prepared will be the User Payload Training Plan (UPTP) to document the training requirements and objectives and how these objectives will be met. It will provide a syllabus of all training courses required, what personnel is required to take each course, and who is responsible for developing each training course. There shall also be high level schedules showing when each phase of training is to be accomplished. The UPTP shall be reviewed, and an appendix created for each increment to highlight and detail any deviations from the base document.

7.4 TRAINER DEVELOPMENT

The preparation of documentation to define the trainers will include analysis of planned experiment operations by study of appropriate documents, participation in TAT meetings, and other mission activities in order to determine experiment trainer requirements (quantity, fidelity, etc..). The documentation to be prepared will be the Payload Trainer Requirements Documents (PTRD Part I, and Part II) to define requirements for trainer development (hardware and software). Each of the PTRD documents (Part I and Part II) will be provided to the DDT&E function of each element developer for the actual design and fabrication of the trainers.

The PTRD Part I defines the operations to be supported, the structure and components of the trainer, the fidelity of those components, training objectives to be supported, verification and validation methodology, requisition, storage, and logistical responsibilities, and PTC interfaces and operations between payloads, if any, for the SSFF experiment trainers. Included in this effort will be analysis of the TAT outcomes such as trainer fidelity, PTC, Training, and Safety requirements.

The PTRD Part II defines the hardware and software requirements, experiment parameter processing requirements, database constraints, event insertion inputs, integration requirements, and required experiment unique equipment for the SSFF trainers. Analysis of experiment operations, PTRD Part I, PTC Operational, Training , and Safety requirements will be crucial in the development of this document. The PTRD Part II will be reviewed for each increment and updated as required to remain current.

Once the PTRDs have been written, Acceptance Test Procedures (TPs) must be developed. Acceptance TPs verify the trainer performance with respect to the requirements levied in the PTRDs such as test objectives, hardware and software requirements, and data flow. Acceptance TPs also define participation in the tests, test procedures, and test support requirements. Development of the Acceptance TPs requires extensive knowledge of the PTRDs and the PTC Capabilities document. This will have to be performed for each of the major SSFF elements and will have to be updated if any changes are made to the trainers.

The implementation of the Acceptance TP will be performed at the Trainer Acceptance Reviews (TARs) with PTC personnel for trainers that are to be integrated into the PTC. The activities associated with the TARs include scheduling when Acceptance TPs will be performed, verifying all objectives/requirements are met, resolving problems by evaluating discrepancies, presenting solutions, assigning action items, and rescheduling

performances if necessary. This will have to be performed for each major element of the SSFF, and will have to be updated if any changes are made to the trainers.

7.5 PAYLOAD INTEGRATION AGREEMENT (PIA) TRAINING ANNEX DEVELOPMENT

The preparation of the Payload Integration Agreement (PIA) Training Annex is the effort to negotiate a formal training agreement between the SSFF major element developers and the SSFP including all training requirements, schedules, and responsibilities. The UPTP will be the starting point for these negotiations from the SSFF element developers perspective. It is anticipated that SSFP personnel will actually develop this document from IROP inputs. However, several iterations will likely take place before an agreement is reached. This implies that the document will have to be reviewed, meetings arranged and attended, and problems resolved for each iteration. These negotiations will be the responsibility of the Core developer.

7.6 TRAINING PREPARATION

The training preparation activities for the Instructor Preparation, Science Background, Individual Payload, Refresher, Safety, and Proficiency Training will include and be based on analysis, the development of courses/courseware, the development of instructor's guides, the verification and validation of training, the development of the SSFF training catalog, the development of the training database, the training of instructors, and scheduling.

The analysis of the UPTP, PIA Training Annex, experiment operations, trainer capabilities, and experiment operating procedures to determine required training for the Crew, POIC Cadre, and PI/PED teams will be accomplished, as well as determining what training may be increment independent and increment dependent.

The development of courses/courseware will involve the preparation of training required to meet the objectives/requirements outlined the UPTP and PIA Training Annex. The development of courses will require grouping training objectives in order to make lessons and then grouping the lessons into courses. This requires reviewing all training requirements and objectives, taking the ones that the SSFF PI/PED team are responsible to train and grouping them into lessons and courses, determining the media to be used to provide instruction, and developing the course. Courses and courseware will be reviewed

for each increment and updated as required to remain current with the increment being trained.

The development of instructors guides for each course will include the development of all materials required to teach the course. An instructor guide includes lesson plans to ensure all required training objectives are covered, summarizes how those objectives will be covered, scripts (or outlines) how the course should be taught, and provides any materials that are needed for the class such as handouts, experiment samples, or video tapes. An instructor guide will be prepared for each and every course required and shall be reviewed and updated whenever its associated course is updated.

The verification/validation of all training prior to actual instruction of Crew, POIC Cadre, PI/PED teams, and/or Instructors will be performed. Typically this type of work involves conducting the training on small test groups and testing comprehension before and after the training. This will have to be done for each lesson in each course to determine if the training objectives are being satisfied by the training being given. Any party that develops training for the SSFF will be responsible for verification/ validation of that training.

The development of the SSFF Training Course Catalog will include listing all courses developed by SSFF training for the training of Crew, POIC Cadre, PI/PED team members, and/or Instructors. This effort includes reviewing all training documentation concerning the Crew, POIC cadre, and all SSFF PI/PED team members involved with SSFF operations. This is to ensure all courses that are required by the Crew and POIC cadre concerning SSFF operations and all courses required to be taken by the PI/PED team are included in the catalog. A brief synopsis of each course must be written for each course along with a list of each position that must take that course prior to being certified. This catalog must then be maintained to incorporate new courses that are required on subsequent increments or deletion of courses that are no longer relevant due to changes in the SSFF or modules. Module developers will also be required to furnish training course information for incorporation into this catalog.

The development of a training database to include all students required to have SSFF training (Crew, POIC cadre, PI/PED team members, Instructors), certification/course requirements for each student, and details of what courses meet what requirements will be performed. This is the effort associated with building a SSFF training database that will interface with TMIS, allowing for inputs into the SSFP training database. The SSFF database will be only for those courses required for SSFF personnel and SSFF courses required for the Crew and POIC cadre. This will be the way in which SSFF instructors interface with the SSFP training database and make inputs into the same. The

SSFF database shall be kept current with all training requirements, students, and courses. This will be the responsibility of the SSFF Core developer.

The training of instructors will be required and will involve the actual performance of training that will ensure instructors have been properly trained and are prepared to perform SSFF training duties. This effort should include training SSFF personnel and PTC personnel on SSFF operations and concepts. For SSFF personnel it will also include instruction on how to instruct a class, how to build instructors guides, and media selection. This training will include FM developer training personnel. For PTC personnel, it will simply cover trainer functions and operations and SSFF operations and concepts. It is assumed that PTC instructors have already been schooled in instruction techniques.

The scheduling tasks to be performed will include the analysis of PDC and PI/PED site capabilities and all increment dependent and increment independent training requirements including instructor vacation schedules in order to develop and maintain long-range plus detailed day-to-day schedules for training sessions at the PDC and PI/PED sites. The preparation of the PI/PED site to support training of the Crew, POIC cadre, and/or PI/PED team members will be performed. This includes ensuring that hardware, software, support documentation, video systems, communications systems, and personnel are present and properly configured to support the objectives of the particular training session.

7.7 PAYLOAD TRAINING COMPLEX (PTC) SUPPORT

The activity of providing support to the PTC involves four areas including PTC trainer integration, development of the PTC training scenarios, PTC training/simulation support, and PTC trainer maintenance. The integration and checkout of the SSFF Trainer(s) into the PTC will be accomplished by providing technical and operational expertise on the SSFF Trainer(s) to aid in troubleshooting and debugging as required prior to the actual training. This is a level of effort to support the six month period from L-18 to L-12 when the trainer will be integrated into the PTC. If any changes are required in the trainer (such as a different furnace module), then the trainer will have to be reintegrated into the PTC after it is checked out.

The development of PTC training scenarios involves the development of SSFF training to be used in the PTC during training and simulations including nominal and off-nominal operations, integration, timelining, and safety procedures. This effort will require a person to be very knowledgeable about SSFF operations, SSFF trainer capabilities, and PTC capabilities. This activity should require quite a bit of up front work with continuous

updates for the differences in each increment. This responsibility should belong to the core developer receiving inputs from the module developers and the PIs.

The PTC training/simulation support will be accomplished at the PTC during training and simulations by providing operational and technical expertise on the trainer. This level of effort work is commensurate with the level of training being performed at the PTC. Currently, the PTC is planning on working two eight hour shifts of training per day five days per week, and running both strings of trainers. This is done to support up to six different sets of crew and POIC cadre that may be in training at any given point in time. This entire time must be supported by at least one SSFF training/trainer expert. Depending on future decisions, this could be an on-call position or a dedicated assignment.

The PTC trainer maintenance effort applies to both configuration control of the SSFF trainers located at the PTC and the actual maintenance of those trainers with respect to periodic maintenance inspections (PMI), troubleshooting, and repair/replacement of parts. This will require someone with a high level of experience with the design and fabrication for both the facility core and furnace module trainers. The lead responsibility for this work will go to the Core developer who will schedule PMIs and will coordinate any repairs that become necessary.

7.8 TRAINING EXECUTION

The actual performance of instructor, science background, individual payload, refresher, proficiency, safety, and PTC training will be accomplished using the courses and courseware developed in the training preparation tasks. This is the effort associated with actually instructing the Crew, POIC cadre, and SSFF PI/PED team members. The science background training will be a calendar based training probably offered twice per year and lasting 3-5 days. The individual payload training will be increment specific and will be dispersed throughout the L-18 to L-12 timeframe. Based on a three utilization flight per year manifest, there will almost always be at least two sets of crews in this phase of training. Refresher and proficiency training will be performed on an as required basis and will occur throughout the training cycle. Safety training will be performed during all phases of training, and PTC training will be performed as required.

7.9 PAYLOAD OPERATIONS AND INTEGRATION CENTER (POIC) TRAINING

It is anticipated that SSFP will have some training required for each of the SSFF element PI/PED training teams. Additionally, there will be courses offered by the POIC that SSFF training personnel will need to take. The SSFF Core developer is also responsible for developing instructor training and will have to administer that to training personnel from the FM developers.

7.10 SCHEDULING, REVIEW SUPPORT, AND MANAGEMENT

The scheduling of major training activities and events will be identified in accordance with deliverables scheduled for each increment. Staffing must permit handling of multiple increments to meet program requirements. A representative schedule of the major training activities for the first and second flight increments is presented in Figure 7.0-1.

The activity to support and attend meetings on training requirements, planning, and conduct is another activity associated with training. This will include supporting and attending milestone operations reviews, meetings/reviews with the Office of Space Science and Applications (OSSA) and/or SSFP training personnel. Examples of these meetings include the TAT meetings, Training Operations Subpanel (TOS) meetings, and Investigator Working Groups (IWGs). The Core developer will be responsible for assuring the proper meetings are attended and the correct inputs made. Instances where the Core developer may want to call a meeting of the people involved in SSFF training, such as a precursor meeting to a TAT, will be accomplished under this activity for both the Core developer and the FM developers.

The training management function for each SSFF element will coordinate SSFF training activities, including maintaining the training database, acting as liaison between the SSFF element project and SSFP in areas concerning training, ensuring proper configuration control of all training courses and courseware (including trainers), developing the applicable SSFF element training schedules, scheduling PI/PED site facilities, PI/PED team members, and instructors for training, and maintaining all SSFF developed documents concerning training.

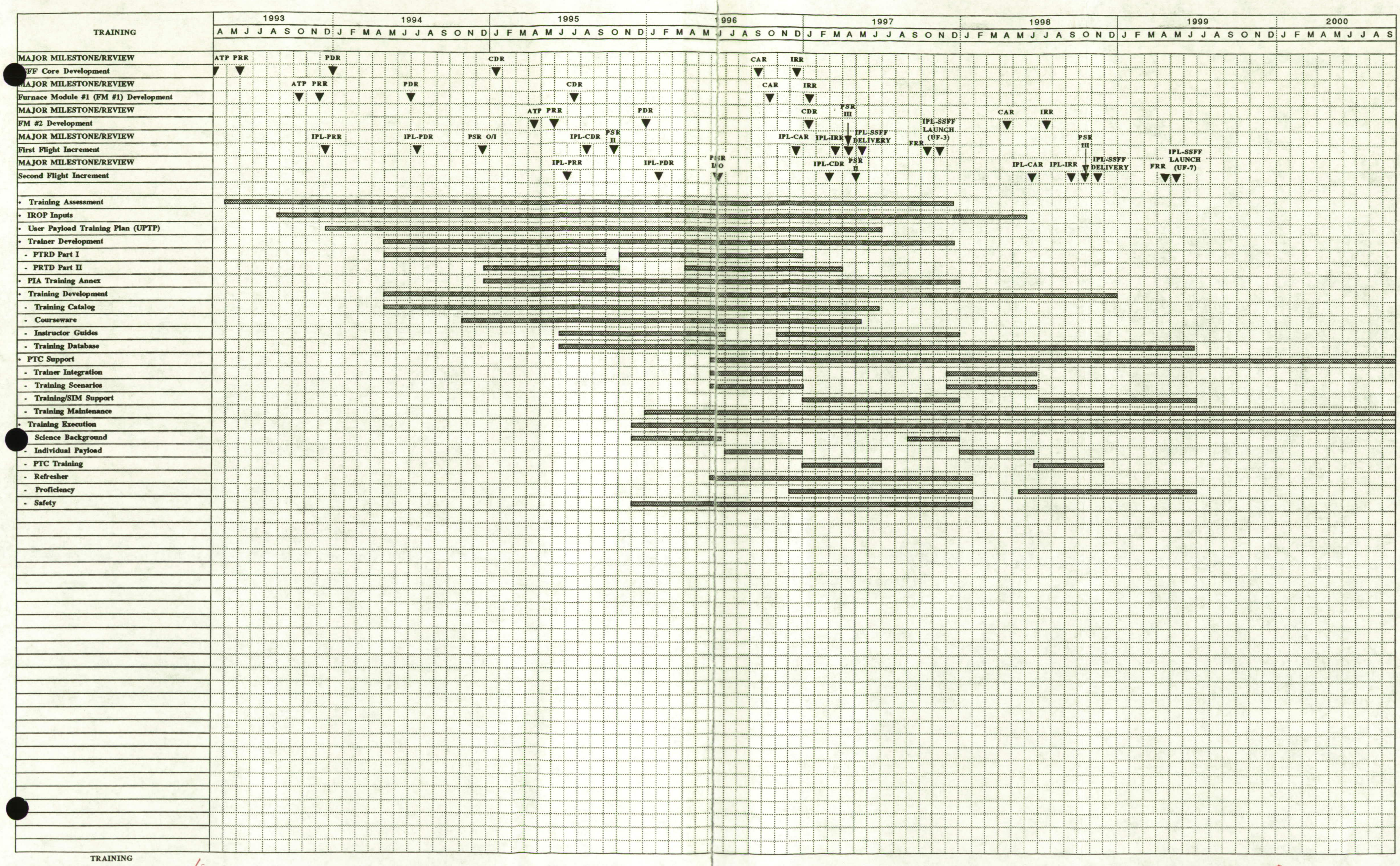


FIGURE 7.0-1 TRAINING ACTIVITIES SCHEDULE

FOLDOUT FRAME 1.

FOLDOUT FRAME 2.

8.0 OPERATIONS

Operations activities will be required to support the SSFF and administer it's planned functions, beginning with initial payload requirements review and continuing through the live of the payload. The operations activities will need to be accomplished by each of the element developers (i.e., the Core developer, the FM1 developer, and the FM2 developer) and will include the general categories of operations management, operations requirements analyses and compatibility assessments, operations training, and the actual execution of planned operations. An overview of the typical operations tasks schedule is presented in Figure 8.0-1.

8.1 OPERATIONS MANAGEMENT

The operations management function will include the activities of Performance Management and Administration (PMA), information management, performance improvement analyses and implementation, and the performance of special studies. The performance management and administration activities include general functions relating to staffing, planning, cost accounting, scheduling, tracking, reporting, and product assurance for the SSFF operational tasks. The nature of the integrated payload and subsequent operations will require meetings between the Core developer, the FM1 developer, the FM2 developer, the Principal Investigators (PIs), and operations control sites personnel, to determine the operations requirements and perform the planning, scheduling, and staffing for each phase of the SSFF development. These working group meetings should take place at least once between each Integrated Payload (IPL) major milestone or review, and will also incorporate activities associated with the payload requirements analyses and compatibility assessments task, which will be detailed in the following section. As the operations tasks proceed with the SSFF design and development maturity, the performance management and administration activities will include the tracking and evaluation of these operations tasks to ensure product quality. The products resulting from operations tasks are documentation inputs pertaining to planning and analyses of payload data requirements presentations to payload project manager, the integration team, and operations sites personnel, and performance during training and mission simulations. The evaluation of products will involve the planning of documentation products content and format, conducting internal reviews of each document product, dry-runs of presentations and discipline-level simulations, monitoring to ensure incorporation and tracking of product changes/modifications, attending major reviews and simulations, and reporting

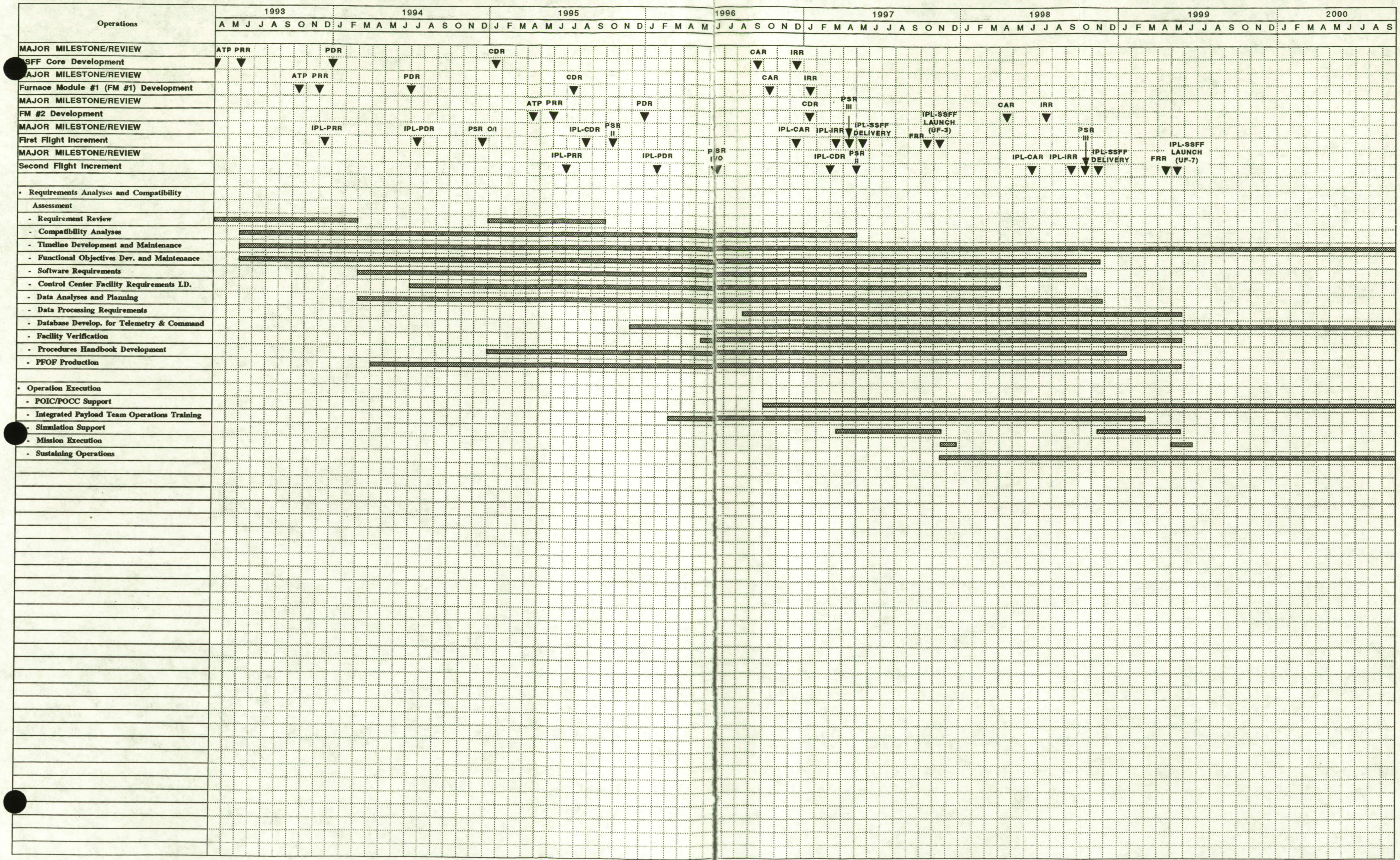


FIGURE 8.0-1 OPERATIONS ACTIVITIES SCHEDULE

FOLDOUT FRAME 1.

FOLDOUT FRAME 2.

improvement activities to operations personnel that will be implemented over the course of the operations design and development. These improvement activities will be concentrated in the area of documentation production.

Information management activities will include information preparation, control, delivery, archiving, and retrieval. These activities will involve the reproduction of documentation, graphics support for SSFF reviews and presentations, action item tracking, and document/drawing tracking and maintenance. These activities will be performed for each article development review (PRR through IRR), integrated payload review (PRR through IRR), and operations specific reviews/meetings. Representative documentation to be produced as a result of providing necessary operations design and development inputs will be identified in the operations requirements analyses and compatibility assessments section 8.2.

Special Studies is a planning/control effort to perform special tasks in support of pre-increment definition, including technical analyses which will input for operations documentation development as deemed necessary by the payload project manager, the integration manager, or the mission manager.

8.2 REQUIREMENTS ANALYSES AND COMPATIBILITY ASSESSMENTS

This activity defines the requirements for flight operations planning for the SSFF, the performance of analyses to determine planned operations compatibility, and also encompasses the effort associated with the conduct of flight operations planning. The operations preliminary design phase begins with a requirements review which will reveal required elements of an operations timeline defining the order and duration of operations tasks necessary to activate and operate the payload. An analysis of the payload data requirements for both command and data return and retention will be performed in order to determine the payload compatibility with required flight and ground system protocols. Operations inputs to related flight definition documents will be derived from these analyses. By the Integrated Payload Preliminary Design Review (IPL-PDR) for each flight increment, a preliminary timeline supported by detailed functional objectives lists is required.

Normally the pre-mission planning design cycles occur three times prior to launch including during the preliminary design cycle, the baseline design cycle, and the final operations design cycle. During the preliminary design cycle, which ends with the

Integrated Payload Critical Design Review (IPL-CDR), each developer must provide early design operations requirements as input to the initial evaluations of system compatibility for the basic mission/experiment timeline and the data handing requirements of the integrated SSFF payload. The baseline design cycle is accomplished between the IPL-CDR and the IPL Flight Operations Review (IPL-FOR) and will require updating of the payload timeline and data management analyses inputs for each SSFF element developer at the IPL-FOR review. Incorporation of implemented RID's from the IPL-FOR along with crew reviews and operations team procedure development produces the final operations design cycle.

Major work elements in the design phase are the timeline development, operations software requirements, control center facility requirements, data analysis and planning, data processing requirements, telemetry and command database development and population, facility verification, and lastly the selection and development of the SSFF flight operations team.

Timeline development activities include providing in Functional Objective (FO) sheets the primary input to define the experiment/facility objectives and documentation of the operational procedures for each SSFF element to be accomplished. Development and documentation of the experiment operations schedule within SSF provided resource allocations is provided to and iterated with POIC personnel

The timeline development effort will include activities to provide a pre-flight integrated payload mission timeline that defines the SSF resource allocations, crew requirements to prepare and/or operate the payload, and ground support personnel requirements to monitor and implement the payload operations. The timeline is generated to ensure that payload requirements and/or restrictions are within the SSF/Orbiter capabilities, and to provide a schedule of crew and experiment activities. The schedule of these activities will be a complete, comprehensive plan for conducting the mission. It drives all other operational activities.

A compatibility assessment timeline is produced by POIC personnel, using element developer inputs, for the Integrated Payload (IPL) requirements review. The compatibility assessment timeline is a simplified version of a complete timeline cycle. It begins with the extraction of experiment/facility requirements and/or restrictions from the experiment requirement documents (ERDs). Clarification and organization of the functional requirements are coordinated with the SSFF element developers and other POIC ground support personnel. The experiment Functional Objective (FO) sheets are then prepared by the individual element operations team for transfer into the POIC provided scheduling system that will also receive input from other mission specific data sources, such as SSF subsystems, (e.g., power, thermal, data,etc.), and JSC operational disciplines. Detailed

activity modeling, data opportunity generation , and data flow analysis are done in later iterations of the timeline.

Additional payload requirements are extracted from documentation such as the Payload Integration Agreement (PIA) Main Volume and the SSF-to-Payload ICD. Updates and clarifications are acquired through meetings and telecons with each element developer. This is a time consuming process with many iterations and coordination efforts required. Travel is usually required on a quarterly basis until L- 6 months and then on a monthly basis. All requirements will be approved by NASA before updating FO sheets.

The timeline is documented in the Flight Definition Document (FDD) and the Flight Planning Annex 2 to the JSC PIP. Further documentation of the timeline is provided in the payload crew activity plan (PCAP) as an input to the Payload Flight Data File(PFDF)

During the flight, the schedule is replanned every 12 hours in response to unplanned events. The pre-flight timeline will be updated in realtime to accommodate replanning requests and contingencies. SSFF developers' input to replanning will be provided as applicable by the operations team for each SSFF element.

Operations software requirements definition occurs in parallel with the operations preliminary design. The operations software requirements assessment will ensure that the flight and ground software compatibility is achieved. Specification of mission specific payload software packages will be defined. SSFF element developer participation in software control boards will ensure early understanding by the element developer teams of software and data handling procedures and tools, such as database inputs and calibration information.

Software requirements definition is divided into two categories, Facility Data Systems and Experiment On-board Software. The Facility Data Systems Software requirements will define the software actions necessary to provide the tools for SSFF elements' health and safety monitoring as well as the planning for facility science data return. Subcategories of these requirements include the following:

a. Communications - Requirements will be developed for all facility software, either commercially available or specially developed, for communication with the POIC and Principal Investigators. Both internal and external interfaces shall be defined.

b. Data Analysis - Requirements will be developed for software used to analyze experiment operational parameters to assess experiment health and safety and performance. Assistance will be provided, as required,

to the Principal Investigators in defining experiment data reduction software tools.

c. Planning - Requirements will be developed or existing planning support tools assessed to insure that each SSFF element operations team has the necessary planning tools to effectively utilize the available mission timeline and react to flight contingencies for optimum science return.

d. Command Generation - Requirements will be developed to optimize the realtime and stored command uploads as they relate to the SSF uplink data system. The SSFF command system for each element must be made compatible with the SSF forward link service, and design input should be made available early in the planning process

e. Display - Requirements will be developed for special display software required in the SSFF facility for experiment operations.

f. Database -Requirements for database handling software will be defined early to insure the ability to effectively handle the FF inputs to the various database(s) flight and ground that will be utilized in the handling and delivery of command and telemetry products.

Experiment On-board Software is the second major software category. The Onboard software is divided into two types, Video and Computer and Data Management.

a. Video - Requirements will be defined for controlling the positioning, magnification, and focus for experiment video sources. Requirements shall be defined for control of video switching hardware, the video frame grabber, and mass storage and video compression devices.

b. Computer and Data Management - Requirements will be developed for: Payload Applications software; Data Management System (DMS) and Communications and Tracking (C&T) system interfaces; mass storage management, and experiment monitoring and control.

Facility requirements development is one of the earliest operations tasks since it is a long lead time item if new or modified facilities are involved. This task involves the

activities to develop, integrate, document, and coordinate SSFF facility requirements. The operations team will develop the facility requirements to include adequate space and supporting systems to support all operations functions including realtime operations, replanning and anomaly investigation. These requirements will be documented in the POIC Interfaces, Services and Support Document (IROP D2.1). It will be necessary to coordinate with the other control elements (i.e., POIC, SSF, etc.) and SSFF element developers for the operations voice and data interfaces for SSFF operations.

The control center facility definition must include space and equipment to support the operations team, usually consisting of seven people, and the anticipated SSFF user ground support equipment. Figure 8.2-1 depicts a typical layout for a user room and conference/problem solving area. It is likely that iterations of these requirements will be necessary due to the fluidity of the POIC/USOC/PPOC operations planning and budgets.

The Facility Verification task includes the activities to plan, prepare, and verify the operation of the SSFF facility systems. All elements of the facility systems, experiment ground support equipment, and external interfaces to the facility will be addressed. These activities shall culminate in readiness certification of the system. This verification task is accomplished after verification by the implementors of the control facility and is the users responsibility to complete prior to acceptance for operations support. This verification effort should utilize, if possible, the flight operations personnel in order to build confidence in the operability of the control center systems.

The Data Management Analysis and Planning task is another early task requiring input and iteration with other operations elements such as POIC and ground network elements. This task very often leads to special studies on data handling and operational procedures required to achieve maximum data return.

The activities required for this task include the performance of all aspects of SSFF data analysis and planning in order to evaluate the flight and ground data systems in terms of their capability to satisfy experiment data requirements, to develop and schedule configurations, and to coordinate execution of data flow schedules during flight operations. Payload data capture, routing, and processing requirements will be developed and documented. Timeline constraints development is a key input to this analysis.

The data flow analysis task is one performed primarily by the POIC data management team. The operations team for the SSFF must provide detailed inputs of data needs within the FO sheets, which are the raw material for producing the POIC Interfaces, Services and Support Document (IROP D2.1) and the User Ground Network Requirements (IROP D2.4). These documents will specify the onboard and ground configuration for data return and command interfaces. The data flow analysis team will

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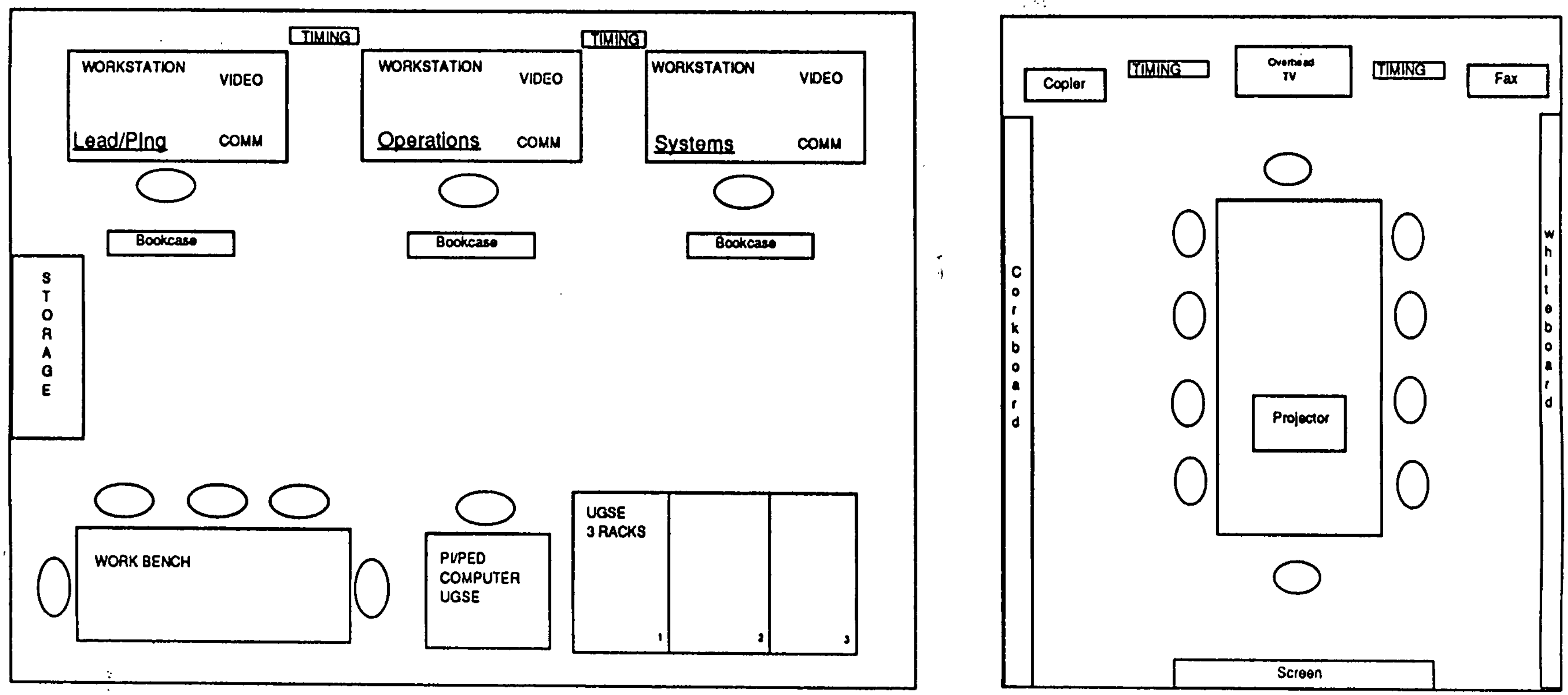


User room

Conference/Work Room

Workstations - function as the primary operations location
UGSEComputer - PI provided computers will house exp unique SW
UGSE racks - special processing of science streams /image processing
Workbench -work area to support UGSE
Equipment storage -for test equipment/tools
Bookcase - operations documents and procedures

Table - work/data review
6 to8 chairs-space for team and consultants
Operations TV -ongoing mission video
Voice monitor - operations voice system
White board - 4x6' minimum
Cork board - records review tool
Fax machine - shared resource acceptable
Copier - shared resource acceptable

Figure 8.2-1. Typical User Room Layout

review and perform negotiations with the SSFF operations team when analysis identifies the need for data system operational changes in support of mission objectives.

The Data Processing Requirements definition task is one that will be later in the schedule. The full detail of these requirements will not be available until after the CDR. Definition and integration of the SSFF experiment data processing requirements will be documented in the Data Processing and Products Requirements Document (IROP D2.5). Definition of production data products (PDP) will include the method, media, and schedule for delivery. Standard data products and associated constraints and format standards will be described. These shall encompass digital data, video data, voice data, and processed data. Development of technical input data to support systems for the processing of data will require detailed knowledge of the command and telemetry measurement list and the database structure. Defining data input interfaces and coordination with implementors will require support to working groups and coordination meetings with ground processing organizations.

The Telemetry/Command Database Development and Verification task is one that is crucial to all aspects of operations. This task will require early planning and coordination since it will be a continuous task throughout the project life. The nature of this task makes it a good candidate for automated maintenance schemes. This effort will include the analysis and definition of experiment telemetry streams and command structures. Another activity will include the completion of inputs for the Master Object Data Base (MODB) objects for telemetry and commanding.

The SSFF operations team development will require coordination activities with each element developer operations team and the POIC cadre to accomplish planned operational objectives. Each team member will be required to perform the following planning tasks as well as operations execution tasks defined in a later section.

The Facility Manager's planning functions include management and integration of the planning activities of the facility systems engineer, S/W and data engineers and support personnel, and the staff scientist. The primary interface between the POIC Science Operations Director and the SSFF Principal Investigators will be the Facility Manager. The staff scientist will provide the primary interface with the SSFF PIs and the mission science planning personnel. The systems engineer will develop functional objective sheets and draft crew procedures. Pre-mission planning coordination with the POIC Payload Activity Planning (PAP) Team, the POIC timeline engineers and the SSFF Principal Investigators will be another systems engineering function. Input to the training

requirements for experiment operations, facility systems and facility and/or experiment GSE is another planning task.

The Software and data systems engineer will provide input to POIC for command shells and the Master Object Data Base (MODB). A requirement definition task will include requirements for Experiment Ancillary Data, Experiment Data Processing Requirements for the Payload Data Services System (PDSS), Experiment Data Ground Distribution Requirements for PDSS and the POIC Experiment Operational Parameters for processing by the POIC.

Another major task for the software and data systems engineer will be the definition of requirements for the Facility Data System hardware and software. The hardware will include equipment for communications, recording, switching and data processing. The software systems requirements to be defined will include Facility Data Systems. Software for communications, data analysis, planning, command generation, display, and database flight systems software requirements are required for video control and compression, computer and data management payload applications, DMS and C&T interfaces, mass storage management, and experiment monitoring and control. The software and data systems engineer activities will include the supervision and assistance in the development, integration and test of all SSFF software.

Pre-mission planning tasks will include coordination with the POIC Data Management Team, Timeline Engineers, and SSFF Principal Investigators.
The activity coordinator/technician will perform administrative support to the facility systems engineer and to the staff scientist.

8.3 OPERATIONS TRAINING

The development of requirements, courseware, and tools for Operations Training is covered in detail in another section of this document. Each element developers operations team will be both a recipient and a conductor of SSFF training. This effort is limited to the training received by the operations team.

Inputs are required regarding mission operations and payload crew training objectives . The entire operations team will receive training on the operations tools and techniques required to function in the SSF/Orbiter operations environment. This training will be by a variety of methods and at various sites including each element developer's site, the PTC, and the ground control center(s). The subjects will include ground and flight data systems, communications (voice,data,video) and procedures.

8.4 OPERATIONS EXECUTION

Operations execution begins approximately 15 months before launch with support by the SSFF operations team to pre-mission integration tests such as the development site pre-ship tests and the more extensive Mission Sequence Tests (MST) and the mission End to End Tests for each flight increment. Additionally, in the final 12 to 15 weeks pre-launch, a number of joint simulations will be held at which all relevant operations organizations and the flight crew will attend.

The SSFF operations team will perform the following functions as part of the on-going flight operations:control and monitoring of health and safety, planning and re-planning, and anomaly resolution. The operations team will be required to perform all of these tasks simultaneously and therefore must have personnel available on all shifts sufficiently cross-trained to be able to function in each area.

The headquarters function will be fulfilled by the facility operations manager and the staff scientist primarily. They will set the operations and science priorities and coordinate with the relevant POIC and other control center planning organizations to insure the maximum adherence to the pre-mission SSFF operations plan..The staff scientist will also be responsible to plan and conduct the science quicklook evaluations to insure proper input to the replanning cycle when science/operations data gathering has not gone according to plan. He will have considerable interaction with the user GSE technician since this GSE will be the primary source of science data available for operations evaluation. The facility manager and staff scientist will also direct the activity coordinator's efforts in interacting with the POIC provided mission planning system.

The health and safety monitoring function will be accomplished primarily by the systems engineer and the software and data systems engineer. The systems engineer will be the primary spokesman to the POIC operations team for the on-going operations task of data monitoring and will provide any realtime assessments of operational status required. The systems engineer also will be a key source of data for anomaly analysis and will coordinate closely with the other SSFF operations team members in assuring anomaly feed back to POIC personnel. The software and data systems engineer will specialize in the flight computer and data management systems monitoring. He will also have an interface with the POIC data flow team to insure the selection of data flow paths and switching options that will arise due to flight and ground reconfigurations.

9.0 LOGISTICS

The hardware and software development for all elements of the SSFF will be performed with evolution from design concept to flight fidelity including Test Article development, Ground Control Experiment Laboratory (GCEL) development, and Flight Unit development. Each of these phases of hardware and software development will require the subsequent development of support equipment. The support equipment development for each of the SSFF elements will be duplication of effort in many cases, and can utilize logistics management between the three separate development and integration contracts to minimize the overall costs. The staggered release of the element contracts will allow necessary design, development, testing and checkout activities to be performed for a particular item, which will be a required support equipment item for another element to perform its checkout activities. The applicability of this approach for the SSFF will be discussed in the following paragraphs.

9.1 HARDWARE AND SOFTWARE LOGISTICS RATIONALE

The Authority to Proceed (ATP) for the SSFF Core will be initiated approximately six months prior to the ATP for FM 1, which will afford the FM 1 developer the use of support equipment that will be provided for and is necessary for the evolutionary development of the SSFF Core. The SSFF Core evolution will begin with the development of a Test Article based on the preliminary flight unit design and analyses activities as described in section 5.1.3. In order to perform the functional checkout activities for the Core Test Article, appropriate GSE must be developed including the following general equipment:

- SSF Resources Simulator GSE
- Handling Equipment GSE
- Special Test GSE
- Special Tools GSE
- Furnace Module Simulator GSE

Based on parallel progress of the Core and FM 1 during the initial design phases of each element, the Core will be able to generate this GSE and perform the necessary functional checkout of the Test Article, and have a six-month lead time to perform any design modification and retest before the FM 1 developer will require the use of specific

pieces of this Core-developed GSE for functional checkout of its Test Article. The specific pieces of GSE that the FM 1 developer would require for functional checkout will include the Core Test Article itself to act as the Core simulator GSE, the SSF Resources simulator to provide resources through the Core simulator, the handling equipment GSE to allow transport of the Core simulator and subsequent hardware, and the special tools GSE developed as required to assemble or operate the Core simulator.

The FM 1 developer will, in turn, provide similar GSE to the Core developer for the Core developer's next phase of design and development, the GCEL Qualification Unit. The initial phase of the FM 1 development will, of course, include the FM 1 Test Article and its required support equipment that will not be provided by the Core developer. The FM 1 GSE that will need to be developed in addition to the Core-provided GSE, will include the following:

- Handling GSE
- Special Test GSE
- Special Tools GSE

The hardware and software logistics management between the Core developer and FM 1 developer for the first flight increment will continue through the development of the Flight Unit for each as depicted in the flow in Figure 9.0-1. The schedule showing the design, development, testing, checkout, and acceptance of GSE status for the Core-developed and FM 1-developed hardware and software to accomplish this logistics management effort is presented in Figure 9.0-2.

The FM 2 developer will also benefit from hardware and software development logistics management. The Core-developed hardware and software used as GSE for the development of the FM 1 articles will have been operated and proven successful during Core functional checkout activities, and FM 1 functional checkout activities prior to delivery to and use by the FM 2 developer during its evolutionary development. The hardware and software logistics management between the Core-developer and the FM 2 developer for the second flight increment is depicted in the flow of Figure 9.0-3. The subsequent schedule showing the design, development, testing, checkout, and acceptance of GSE status for the Core-developed and FM 2-developed hardware and software to accomplish this logistics management effort is presented in Figure 9.0-4.

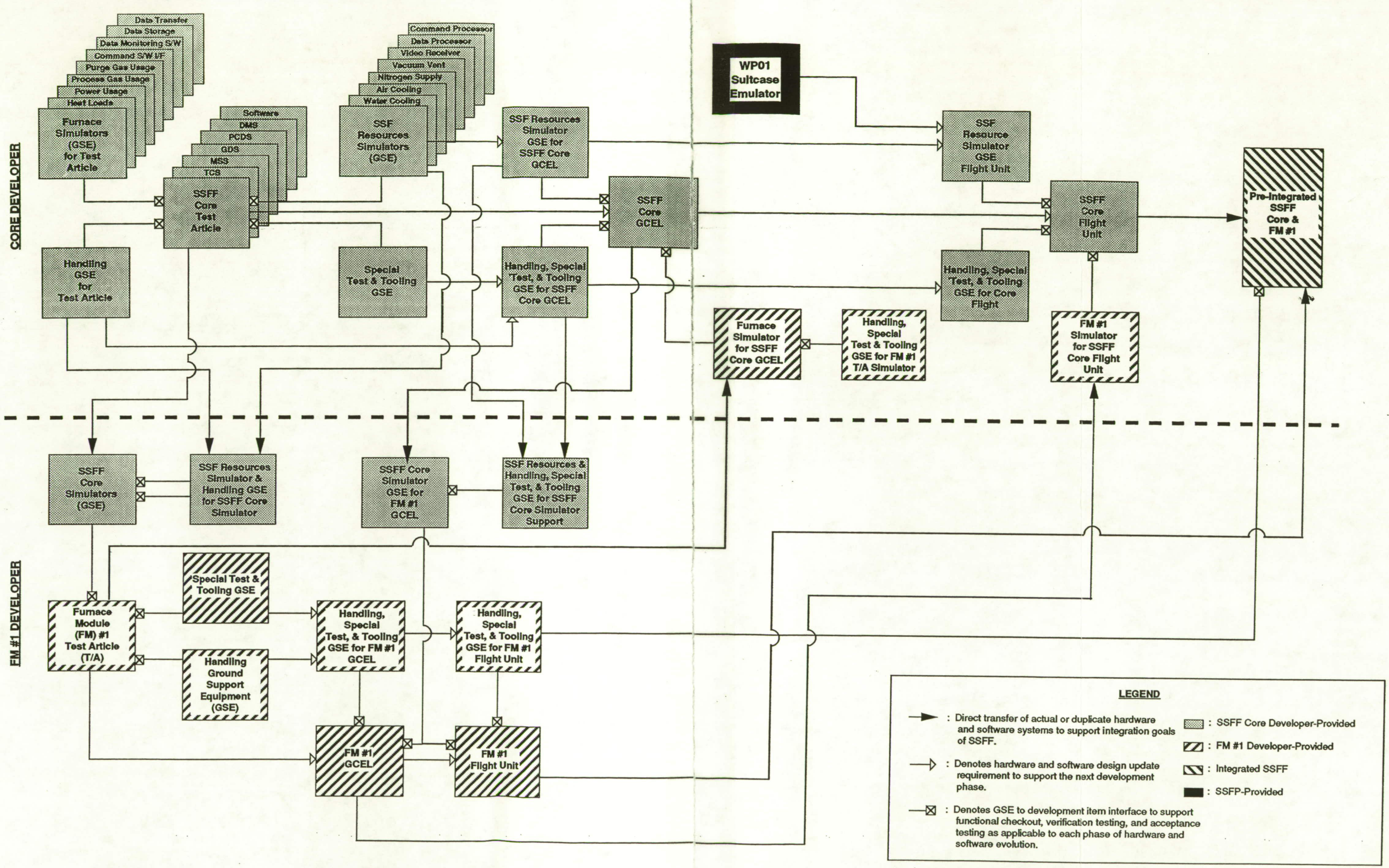
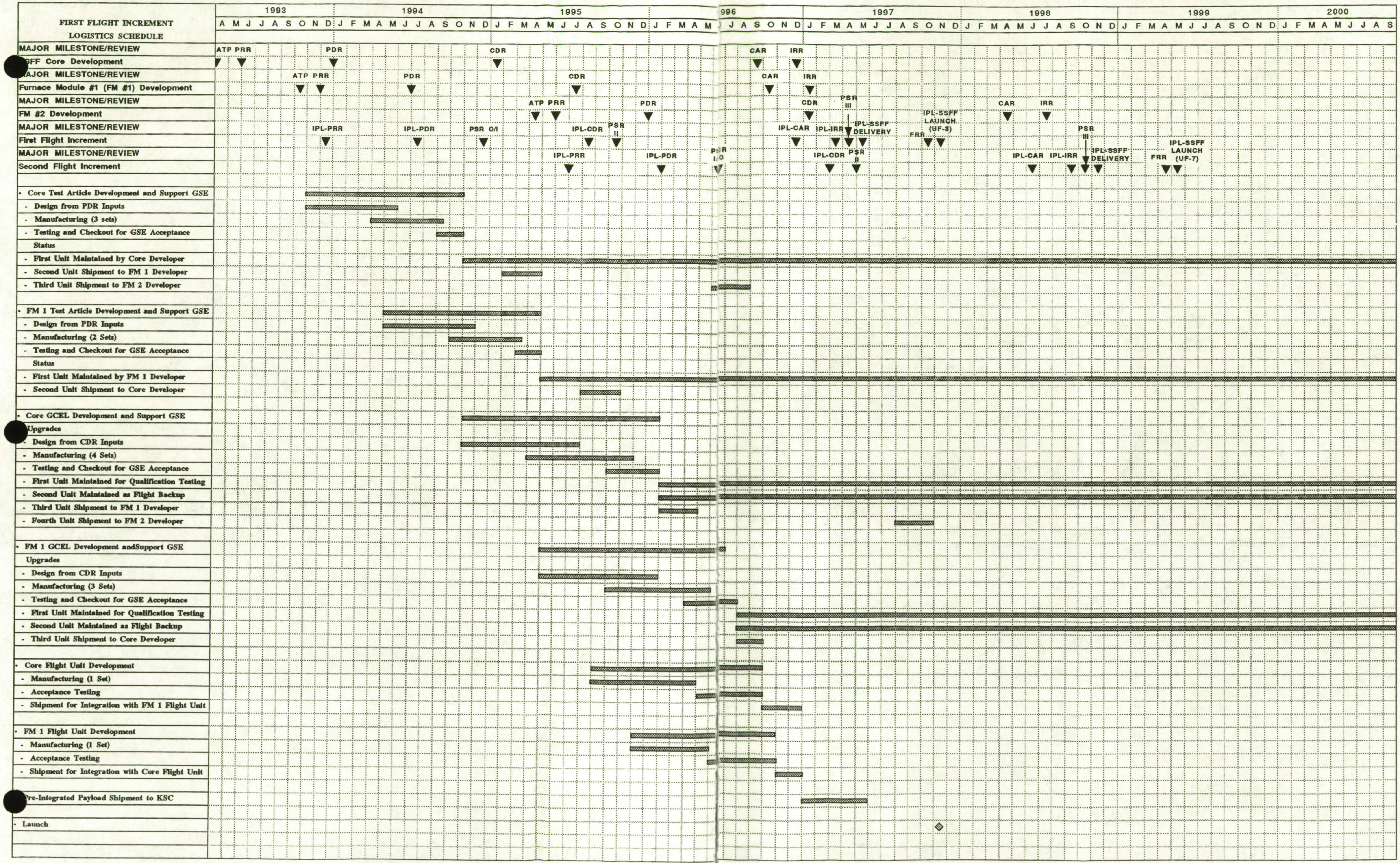


FIGURE 9.0-1 FIRST FLIGHT INCREMENT HARDWARE AND SOFTWARE DEVELOPMENT LOGISTICS APPROACH FLOW

FOLDOUT FRAME 1.

FOLDOUT FRAME 2.



FOLDOUT FRAME 1.

FIGURE 9.0-2 FIRST FLIGHT INCREMENT HARDWARE AND SOFTWARE DEVELOPMENT LOGISTICS MANAGEMENT APPROACH

FOLDOUT FRAME 2.

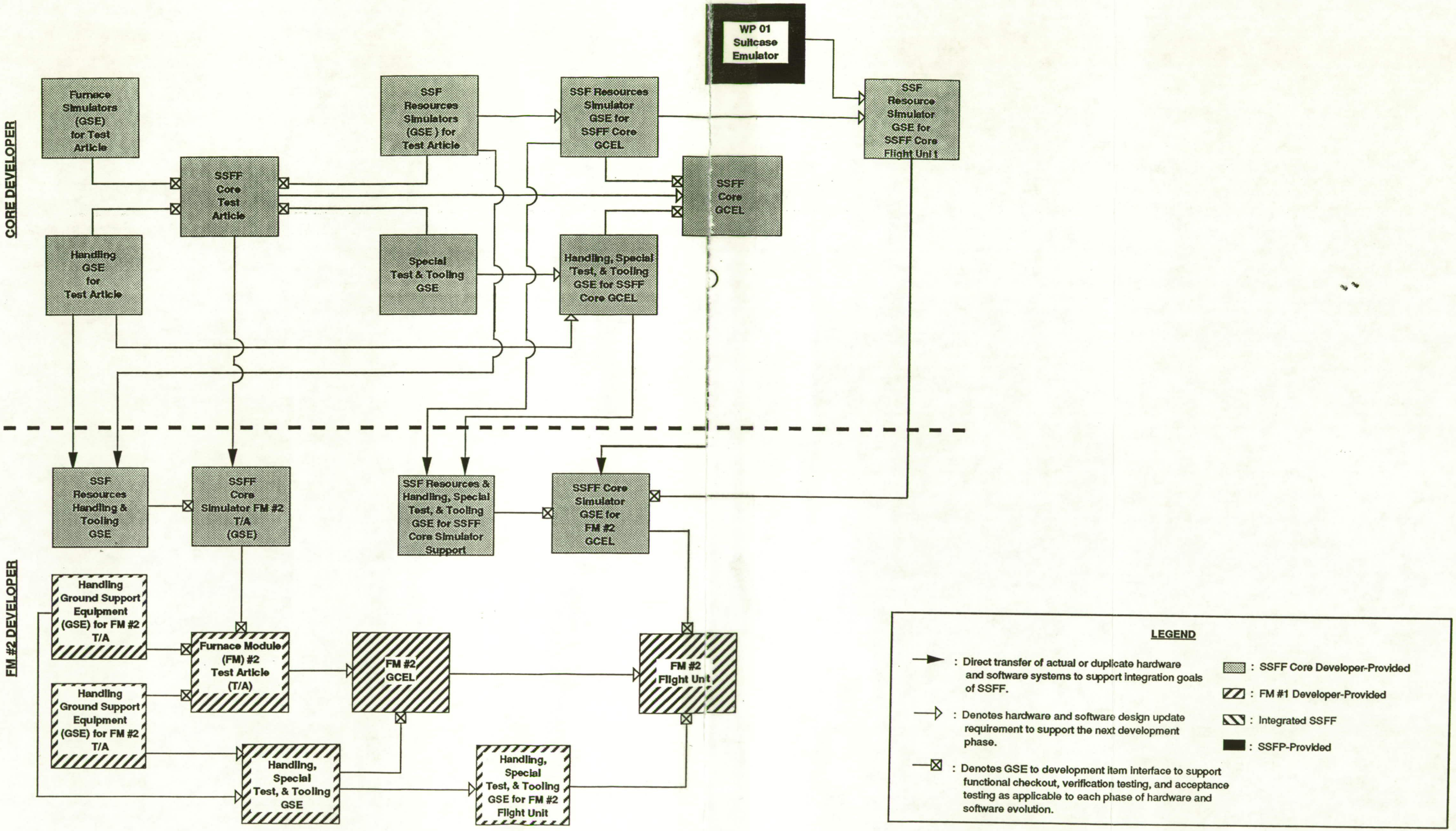
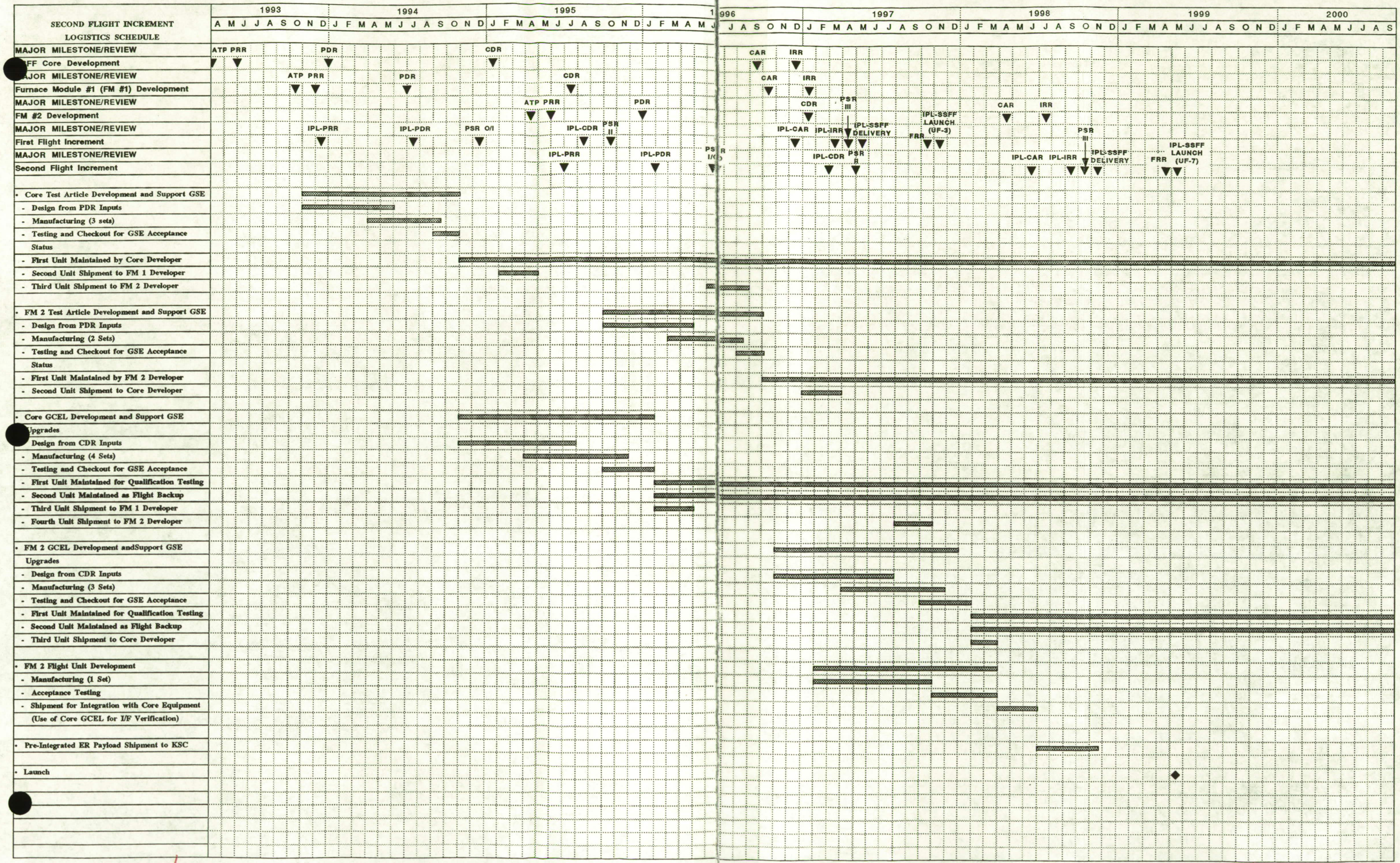


FIGURE 9.0-3 SECOND FLIGHT INCREMENT HARDWARE AND SOFTWARE DEVELOPMENT LOGISTICS APPROACH FLOW

FOLDOUT FRAME 1.

FOLDOUT FRAME 2.



FOLDOUT FRAME 1

FIGURE 9.0-4 SECOND FLIGHT INCREMENT HARDWARE AND SOFTWARE DEVELOPMENT LOGISTICS MANAGEMENT APPROACH

FOLDOUT FRAME 2.

The actual hardware and software developed for each phase of each article's development will not be provided and/or delivered to the complement developer. Duplicate sets of the hardware and software would be developed and provided instead, as the original equipment would be needed to further the next design and development phase of each article. The duplication of these hardware and software sets as opposed to independent development of these sets by each developer will incur a lesser development cost. The number of each of the major hardware and software sets required to be provided by each developer, and the subsequent rationale for duplication of these sets will be discussed in the ensuing paragraphs.

The hardware and software sets to be provided by the Core-developer, the number of each set, and the rationale for providing each original and duplicate set is presented in the following list:

- Test Article Hardware and Software Set (Three (3) Units)

  - The first set of Core Test Article hardware and software will be required to prove the design critical technology and functionality of the design approach. After this unit completes successful functional checkout, it will be maintained to perform any design and operability testing to support the development of the Core GCEL during the next design and development phase for the Flight Unit.

  - The second set of Core Test Article hardware and software will be required as Core simulator GSE to support the development of the FM 1 Test Article. This unit will be required to be maintained by the FM 1 developer to perform any design and operability testing to support the development of the FM 1 GCEL during the next design and development phase for the Flight Unit. Also, this unit will be required along with the FM 1 Test Article to initiate sample characterization activities, and sample testing and preparation activities by the PIs over the course of the overall SSFF development.

  - The third set of Core Test Article hardware and software will be required as Core simulator GSE to support the development of the FM 2 Test Article. This unit will be required to be maintained by the FM 2 developer to perform any design and operability testing to support the development of the

FM 2 GCEL during the next design and development phase for the Flight Unit. Also, this unit will be required along with the FM 2 Test Article to initiate sample characterization activities, and sample testing and preparation activities by the PIs over the course of the overall SSFF development.

- Test Article SSF Resource Simulator GSE (Three (3)Units)

  - The first set of Test Article SSF Resource Simulator GSE will be required to simulate the functional interface of resources that the Core will be required to receive and control for distribution and use as required by the FMs and the complement Core subsystems. This GSE will simulate the USL interface during the Core Test Article development and functional checkout. This set of GSE will be maintained by the Core developer to support the performance of design and operability testing using the Core Test Article for the development of the Core GCEL during the next design and development phase of the Core Flight Unit.

  - The second set of Test Article SSF Resource Simulator GSE will be required to support the Core simulator GSE during FM 1 Test Article development and subsequent sample characterization, testing, and preparation activities.

  - The third set of Test Article SSF Resource Simulator GSE will be required to support the Core simulator GSE during FM 2 Test Article development and subsequent sample characterization, testing, and preparation activities.

- Test Article Furnace Simulator GSE (One (1) Unit)

  - The Test Article Furnace Simulator GSE will be required to simulate the loads that FM 1 and FM 2 will put on the Core and subsequent SSF resources. This unit will be utilized only during the development of the Core Test Article, as the logistics management will provide for the use of GSE developed by the FM developers as previously described to simulate the furnace loads during the succeeding phases of the Core development.

- Test Article Handling GSE (Three (3) Units)

- The first set of Test Article Handling GSE will be required to support the transport and handling of the Core Test Article during the development and functional checkout of the Core Test Article. This unit will be maintained for the subsequent support of the Test Article during the performance of design and operability testing for the Core GCEL development during the next phase of the design and development of the Core Flight Unit.

- The second set of Test Article Handling GSE will be required to support the Core simulator GSE during FM 1 Test Article development and subsequent sample characterization, testing, and preparation activities.

- The third set of Test Article Handling GSE will be required to support the Core simulator GSE during FM 2 Test Article development and subsequent sample characterization, testing, and preparation activities.

• Test Article Special Test GSE (One (1) Unit)

- The Test Article Special Test GSE will be required to support any component, subassembly, or subsystem testing prior to integration of the Core Test Article for functional checkout. This GSE is required to perform testing to ensure safety of ground personnel as well as determine performance characteristics of chosen or designed components, subassemblies, and subsystems before investing additional time and effort into the further development and use of this design equipment in the Core. This GSE will be maintained by the Core developer for upgrade and use on the testing of GCEL and Flight Unit hardware and software.

• Test Article Special Tools GSE (Three (3) Units)

- The first set of this Test Article Special Tools GSE will be required for special assembly or operation of the Core Test Article subsystems or subassemblies during the Test Article development phase.

- The second set of this Test Article Special Tools GSE will be required to support the assembly and/or operation of the Core simulator GSE during the FM 1 development and functional checkout.

- The third set of this Test Article Special Tools GSE will be required to support the assembly and/or operation of the Core simulator GSE during the FM 2 development and functional checkout.

• GCEL Hardware and Software Set (Four (4) Units)

- The first set of GCEL hardware and software will be required to perform qualification testing of the Core design at the component and then subsystem level. This unit will prove the detailed design technology and functionality, and will undergo all testing to prove the design of the Core to perform its required functions and simultaneously withstand the maximum ranges of environmental extremes to which the Core will be subjected during its lifetime. The use of this unit during qualification testing will invalidate it for use as flight backup equipment.

- The second set of GCEL hardware and software will be required to be maintained by the Core developer to be utilized as a flight backup, as well as to provide a flight fidelity physical and functional interface for the FM 2 interface verification prior to the second flight increment. This unit may also be utilized to perform parallel ground operation for troubleshooting in the event of on-orbit anomalies with the Flight Unit.

- The third set of GCEL hardware and software will be required as Core simulator GSE for the FM 1 developer to use during the FM 1 GCEL development. This simulator GSE will be maintained by the FM 1 developer following FM 1 GCEL functional checkout to perform sample characterization, testing, and preparation of FM 1 samples prior to the first flight increment of the SSFF, and to perform parallel ground processing of samples in conjunction with the FM 1 GCEL during the on-orbit processing of FM 1 samples in the USL.

- The fourth set of GCEL hardware and software will be required as Core simulator GSE for the FM 2 developer to use during the FM 2 GCEL development. This simulator GSE will be maintained by the FM 2 developer following FM 2 GCEL functional checkout to perform sample characterization, testing, and preparation of FM 2 samples prior to the first flight increment of the SSFF, and to perform parallel ground processing of samples in conjunction with the FM 2 GCEL during the on-orbit processing of FM 2 samples in the USL.

- GCEL SSF Resources Simulator GSE (Three (3) Units)

  - The first set of the GCEL SSF Resources Simulator GSE will be required to support the Core qualification testing with the Core GCEL Qualification Unit. This unit will be dedicated to the Core GCEL qualification unit during all functional checkout testing activities as required. This GSE may consist of upgrades to the SSF Resources Simulator GSE developed to support the proof of design for the Core Test Article. The completion of qualification testing on the Core GCEL qualification unit will be complete prior to the initiation of the activities performed by the flight backup unit GCEL to provide for FM 2 interface verification, and possible troubleshooting. This GSE will be required to support the flight backup unit GCEL during these activities.

  - The second set of GCEL SSF Resources Simulator GSE will be required to support the Core simulator GCEL GSE during the development of the FM 1 GCEL. This GSE will be maintained by the FM 1 developer during sample processing activities both prior to and parallel to on-orbit processing in the USL.

  - The third set of GCEL SSF Resources Simulator GSE will be required to support the Core simulator GCEL GSE during the development of the FM 2 GCEL. This GSE will be maintained by the FM 2 developer during sample processing activities both prior to and parallel to on-orbit processing in the USL.

- GCEL Handling GSE (Three (3) Units)

  - The first set of GCEL Handling GSE will be required to support the transport and handling of the Core GCEL Qualification Unit. This GSE unit will be dedicated to the Core GCEL qualification unit during all functional checkout testing activities as required. This GSE may consist of upgrades to the Handling GSE developed to support the Core Test Article. The completion of qualification testing on the Core GCEL qualification unit will be complete prior to the initiation of the activities performed by the flight backup unit GCEL to provide for FM 2 interface verification, and possible troubleshooting. This GSE will be required to support the flight backup unit GCEL during these activities.

  - The second set of GCEL Handling GSE will be required to support the Core simulator GCEL GSE during the development of the FM 1 GCEL. This GSE will be maintained by the FM 1 developer during sample processing activities both prior to and parallel to on-orbit processing in the USL.

  - The third set of GCEL Handling GSE will be required to support the Core simulator GCEL GSE during the development of the FM 2 GCEL. This GSE will be maintained by the FM 2 developer during sample processing activities both prior to and parallel to on-orbit processing in the USL.

- GCEL Special Test GSE (One (1) Unit)

  - The GCEL Special Test GSE will be required to support any component, subassembly, or subsystem testing prior to integration of the Core GCEL for functional checkout. This GSE is required to perform testing to ensure safety of ground personnel as well as determine performance characteristics of chosen or designed components, subassemblies, and subsystems before investing additional time and effort into the further development and use of this design equipment in the Core. This GSE will generally be an upgrade from the special tools GSE developed for the Test Article.

- GCEL Special Tools GSE (Three (3) Units)

- The first set of this GCEL Special Tools GSE will be required for special assembly or operation of the Core GCEL subsystems or subassemblies during the GCEL development phase.

- The second set of this GCEL Special Tools GSE will be required to support the assembly and/or operation of the Core simulator GSE during the FM 1 development and functional checkout.

- The third set of this GCEL Special Tools GSE will be required to support the assembly and/or operation of the Core simulator GSE during the FM 2 development and functional checkout.

• Flight Unit (One (1) Unit)

  - The Flight Unit will be developed and integrated with the FM 1 Flight Unit at the Core developer's site. The Core Flight Unit will undergo certification/acceptance functional testing per the Core development program manager to prove compliance with the CEI specifications. The Core Flight Unit will also be shipped to the KSC integration site along with the FM 1 Flight Unit equipment as a pre-integrated payload, with the exception of one rack structure, which will be utilized during pre-integration of the FM 2 for the second flight increment. Interface verification will be performed on the Flight Unit at KSC during nominal physical integration activities.

• Flight Unit SSF Resource Simulator GSE (One (1) Unit)

  - The SSF Resource Simulator GSE will be required to perform certification/acceptance testing and functional checkout of the Core Flight Unit, and also for the pre-integrated payload (i.e., Core and FM 1) testing and functional interface verification and checkout prior to shipment to KSC for integration into the Logistics Module. This simulator GSE will be an upgrade from the SSF Resource simulators developed to support the Core Test Article development and the Core GCEL development, and will also include modification based on the WP01 Suitcase Emulator, which will be

the NASA-developed SSF Resource simulator required for interface verification and checkout.

- Flight Unit Handling GSE (One (1) Unit)

  - The Flight Unit Handling GSE will be required during the first flight increment to perform ground handling operations of the integrated payload during certification/acceptance testing and checkout, payload rack integration testing and checkout, and during integration of the payload into the Logistics Module at KSC. This GSE will be required to interface with and successfully handle the integrated payload including the FM 1 Flight Unit, since the FM 1 Flight Unit will interface with the Core-developed rack structure.

- Flight Unit Special Test GSE (One (1) Unit)

  - The Core Flight Unit Special Test GSE will be required to perform specific verification tests for the Flight Unit acceptance by the Integration Readiness Review (IRR) for the Core. This test equipment will be an update to the GSE developed during the Core GCEL qualification testing and design approach verification required to test specific components, subassemblies, or subsystems.

- Flight Unit Special Tools GSE (One (1) Unit)

  - The Core Flight Unit Special Tools GSE will be required to support unique assembly or operations associated with the Core. This GSE will be an update to the GSE developed for assembly and operation activities during the Core Test Article and GCEL development phases.

The philosophy for providing the hardware and software required for development by the FM 1 developer to support the presented logistics management approach is similar to the philosophy used in determining the hardware and software development requirements for the Core. The hardware and software sets to be provided by the FM 1 developer, the number of each set, and the rationale for providing each original and duplicate set is presented in the following list:

- FM 1 Test Article Hardware and Software Set (Two (2) Units)

  - The first set of FM 1 Test Article hardware and software will be required to prove the design critical technology and functionality of the design approach. After this unit completes successful functional checkout, it will be maintained to perform any design and operability testing to support the development of the FM 1 GCEL during the next design and development phase for the Flight Unit.

  - The second set of FM 1 Test Article hardware and software will be required as FM 1 simulator GSE to support the development of the Core GCEL. This unit will be required to be maintained by the Core developer to perform any design and operability testing to support the development of the Core GCEL during the next design and development phase for the Flight Unit. Also, this unit will be required along with the Core Test Article to initiate sample characterization activities, and sample testing and preparation activities by the PIs over the course of the overall SSFF development. This unit will also be used along with the Core Test Article to support the second flight increment FM 2 Test Article development to simulate the overall SSFF interface and loads configuration for functional checkout.

- FM 1 Test Article Handling GSE (Two (2) Units)

  - The first set of Test Article Handling GSE will be required to support the transport and handling of the FM 1 Test Article during the development and functional checkout of the FM 1 Test Article. This unit will be maintained for the subsequent support of the Test Article during the performance of design and operability testing for the FM 1 GCEL development during the next phase of the design and development of the FM 1 Flight Unit.

  - The second set of Test Article Handling GSE will be required to support the FM 1 simulator GSE during the Core GCEL development.

- FM 1 Test Article Special Test GSE (One (1) Unit)

- The Test Article Special Test GSE will be required to support any component, subassembly, or subsystem testing prior to integration of the FM 1 Test Article for functional checkout. This GSE is required to perform testing to ensure safety of ground personnel as well as determine performance characteristics of chosen or designed components, subassemblies, and subsystems before investing additional time and effort into the further development and use of this design equipment in the Core. This GSE will be maintained by the FM 1 developer for upgrade and use on the testing of GCEL and Flight Unit hardware and software.

- FM 1 Test Article Special Tools GSE (Two (2) Units)

  - The first set of this Test Article Special Tools GSE will be required for special assembly or operation of the FM 1 Test Article subsystems or subassemblies during the Test Article development phase.

  - The second set of this Test Article Special Tools GSE will be required to support the assembly and/or operation of the FM 1 simulator GSE during the Core GCEL development and functional checkout.

- FM 1 GCEL Hardware and Software Set (Three (3) Units)

  - The first set of GCEL hardware and software will be required to perform qualification testing of the FM 1 design at the component and then subsystem level. This unit will prove the detailed design technology and functionality, and will undergo all testing to prove the design of the FM 1 to perform its required functions and simultaneously withstand the maximum ranges of environmental extremes to which the FM 1 will be subjected during its lifetime. The use of this unit during qualification testing will invalidate it for use as flight backup equipment.

  - The second set of GCEL hardware and software will be required to be maintained by the FM 1 developer to be utilized as a flight backup. This unit will also be utilized to perform parallel ground operation of on-orbit sample processing, as well as for sample characterization, preparation, and

testing. This FM 1 GCEL may also be used for troubleshooting in the event of on-orbit anomalies with the Flight Unit.

- The third set of GCEL hardware and software will be required as FM 1 simulator GSE for the Core developer to use during the Core Flight Unit development and checkout. The checkout of the Core Flight Unit using this FM 1 simulator references support activities required to be performed by the Core developer to satisfy CEI specifications functional acceptance, and subsequent verification independent of the intended integrated payload for the first flight increment. Also, this FM 1 GCEL will be maintained along with the Core GCEL for interface verification and operational checkout of the FM 2 within the entire SSFF configuration during the second flight increment for certification/acceptance and integration readiness.

- FM 1 GCEL Handling GSE (Two (2) Units)

  - The first set of FM 1 GCEL Handling GSE will be required to support the transport and handling of the FM 1 GCEL Qualification Unit. This GSE unit will be dedicated to the FM 1 GCEL qualification unit during all functional checkout testing activities as required. This GSE may consist of upgrades to the Handling GSE developed to support the FM 1 Test Article. The completion of qualification testing on the FM 1 GCEL qualification unit will be complete prior to the initiation of the activities performed by the flight backup unit GCEL to provide for FM 2 interface verification, and possible troubleshooting. This GSE will be required to support the flight backup unit GCEL during these activities.

  - The second set of GCEL Handling GSE will be required to support the FM 1 simulator GCEL GSE during the development of the Core Flight Unit.

- FM 1 GCEL Special Test GSE (One (1) Unit)

  - The GCEL Special Test GSE will be required to support any component, subassembly, or subsystem testing prior to integration of the FM 1 GCEL for functional checkout. This GSE is required to perform testing to ensure safety of ground personnel as well as determine performance characteristics

of chosen or designed components, subassemblies, and subsystems before investing additional time and effort into the further development and use of this design equipment in the Core. This GSE will generally be an upgrade from the special tools GSE developed for the Test Article.

- GCEL Special Tools GSE (Two (2) Units)

  - The first set of this GCEL Special Tools GSE will be required for special assembly or operation of the FM 1 GCEL subsystems or subassemblies during the GCEL development phase.

  - The second set of this GCEL Special Tools GSE will be required to support the assembly and/or operation of the FM 1 simulator GSE during the Core Flight Unit development and functional checkout.

- Flight Unit (One (1) Unit)

  - The Flight Unit will be developed and integrated with the Core Flight Unit at the Core developer's site. The FM 1 Flight Unit will undergo certification/acceptance functional testing per the FM 1 development program manager to prove compliance with the CEI specifications. The FM 1 Flight Unit will also be shipped to the KSC integration site along with the Core Flight Unit equipment as a pre-integrated payload, with the exception of one rack structure, which will be utilized during pre-integration of the FM 2 for the second flight increment. Interface verification will be performed on the Flight Unit at KSC during nominal physical integration activities.

- Flight Unit Handling GSE (One (1) Unit)

  - The Flight Unit Handling GSE will be required during the first flight increment to perform ground handling operations of the integrated payload during certification/acceptance testing and checkout, payload rack integration testing and checkout, and during integration of the payload into the Logistics Module at KSC. This GSE will be required to interface with and successfully handle the integrated payload including the FM 1 Flight

Unit, since the FM 1 Flight Unit will interface with the Core-developed rack structure.

- Flight Unit Special Test GSE (One (1) Unit)

  - The FM 1 Flight Unit Special Test GSE will be required to perform specific verification tests for the Flight Unit acceptance by the Integration Readiness Review (IRR) for the Core. This test equipment will be an update to the GSE developed during the Core GCEL qualification testing and design approach verification required to test specific components, subassemblies, or subsystems.

- Flight Unit Special Tools GSE (One (1) Unit)

  - The FM 1 Flight Unit Special Tools GSE will be required to support unique assembly or operations associated with the FM 1. This GSE will be an update to the GSE developed for assembly and operation activities during the CFM 1 Test Article and GCEL development phases.

The philosophy for providing the hardware and software required for development by the FM 2 developer to support the presented logistics management approach is similar to the philosophy used in determining the hardware and software development requirements for the Core and FM 2. The hardware and software sets to be provided by the FM 2 developer, the number of each set, and the rationale for providing each original and duplicate set is presented in the following list:

- FM 2 Test Article Hardware and Software Set (Two (2) Units)

  - The first set of FM 2 Test Article hardware and software will be required to prove the design critical technology and functionality of the design approach. After this unit completes successful functional checkout, it will be maintained to perform any design and operability testing to support the development of the FM 2 GCEL during the next design and development phase for the Flight Unit.

- The second set of FM 2 Test Article hardware and software will be required as FM 2 simulator GSE to support the performance of any design or operability testing on the Core GCEL to confirm the Core and FM 2 interface at the Core developer's site. Also, this unit will be required along with the Core Test Article or GCEL to initiate sample characterization activities, and sample testing and preparation activities by the PIs over the course of the overall SSFF development.

• FM 2 Test Article Handling GSE (Two (2) Units)

  - The first set of Test Article Handling GSE will be required to support the transport and handling of the FM 2 Test Article during the development and functional checkout of the FM 2 Test Article. This unit will be maintained for the subsequent support of the Test Article during the performance of design and operability testing for the FM 2 GCEL development during the next phase of the design and development of the FM 2 Flight Unit.

  - The second set of Test Article Handling GSE will be required to support the FM 2 simulator GSE during the Core developer interface confirmation and use by the PIs for sample characterization and preparation.

• FM 2 Test Article Special Test GSE (One (1) Unit)

  - The Test Article Special Test GSE will be required to support any component, subassembly, or subsystem testing prior to integration of the FM 2 Test Article for functional checkout. This GSE is required to perform testing to ensure safety of ground personnel as well as determine performance characteristics of chosen or designed components, subassemblies, and subsystems before investing additional time and effort into the further development and use of this design for GCEL and Flight Unit development. This GSE will be maintained by the FM 2 developer for upgrade and use on the testing of GCEL and Flight Unit hardware and software.

• FM 2 Test Article Special Tools GSE (Two (2) Units)

  - The first set of this Test Article Special Tools GSE will be required for special assembly or operation of the FM 2 Test Article subsystems or subassemblies during the Test Article development phase.

  - The second set of this Test Article Special Tools GSE will be required to support the assembly and/or operation of the FM 2 simulator GSE during the Core developer interface confirmation, and sample activities by the PIs.

- FM 2 GCEL Hardware and Software Set (Three (3) Units)

  - The first set of GCEL hardware and software will be required to perform qualification testing of the FM 2 design at the component and then subsystem level. This unit will prove the detailed design technology and functionality, and will undergo all testing to prove the design of the FM 2 to perform its required functions and simultaneously withstand the maximum ranges of environmental extremes to which the FM 2 will be subjected during its lifetime. The use of this unit during qualification testing will invalidate it for use as flight backup equipment.

  - The second set of GCEL hardware and software will be required to be maintained by the FM 2 developer to be utilized as a flight backup. This unit will also be utilized to perform parallel ground operation of on-orbit sample processing, as well as for sample characterization, preparation, and testing. This FM 2 GCEL may also be used for troubleshooting in the event of on-orbit anomalies with the Flight Unit in conjunction with the Core GCEL GSE.

  - The third set of GCEL hardware and software will be required as FM 2 simulator GSE for the Core developer to perform interface confirmation testing and additional sample activities by the PIs as required along with the Core GCEL. The checkout of the Core GCEL (flight backup) using this FM 2 simulator references support activities required to be performed by the Core developer to satisfy CEI specifications functional acceptance, and subsequent verification independent of the intended integrated payload for the first flight increment.

- FM 2 GCEL Handling GSE (Two (2) Units)

  - The first set of FM 2 GCEL Handling GSE will be required to support the transport and handling of the FM 2 GCEL Qualification Unit. This GSE unit will be dedicated to the FM 2 GCEL qualification unit during all functional checkout testing activities as required. This GSE may consist of upgrades to the Handling GSE developed to support the FM 2 Test Article.

  - The second set of GCEL Handling GSE will be required to support the FM 2 simulator GCEL GSE during the Core developer interface confirmation and PI sample activities.

- FM 2 GCEL Special Test GSE (One (1) Unit)

  - The GCEL Special Test GSE will be required to support any component, subassembly, or subsystem testing prior to integration of the FM 2 GCEL for functional checkout. This GSE is required to perform testing to ensure safety of ground personnel as well as determine performance characteristics of chosen or designed components, subassemblies, and subsystems before investing additional time and effort into the further development and use of this design during FM 2 Flight Unit development. This GSE will generally be an upgrade from the special tools GSE developed for the Test Article.

- GCEL Special Tools GSE (Two (2) Units)

  - The first set of this GCEL Special Tools GSE will be required for special assembly or operation of the FM 2 GCEL subsystems or subassemblies during the GCEL development phase.

  - The second set of this GCEL Special Tools GSE will be required to support the assembly and/or operation of the FM 2 simulator GSE during the Core Flight Unit development and functional checkout.

- Flight Unit (One (1) Unit)

- The Flight Unit will be developed and integrated with the Core equipment (the rack structure) at the Core developer's site. The FM 2 Flight Unit will undergo certification/acceptance functional testing per the FM 2 development program manager to prove compliance with the CEI specifications. The FM 2 Flight Unit will also be shipped to the KSC integration site along with the Core Flight Unit equipment as a pre-integrated payload. Interface verification will be performed on the Flight Unit at KSC during nominal physical integration activities.

- Flight Unit Handling GSE (One (1) Unit)

  - The Flight Unit Handling GSE will be required during the first flight increment to perform ground handling operations of the integrated payload during certification/acceptance testing and checkout, payload rack integration testing and checkout, and during integration of the payload into the Logistics Module at KSC. This GSE will be required to interface with and successfully handle the integrated payload including the FM 2 Flight Unit, since the FM 2 Flight Unit will interface with the Core-developed rack structure.

- Flight Unit Special Test GSE (One (1) Unit)

  - The FM2 Flight Unit Special Test GSE will be required to perform specific verification tests for the Flight Unit acceptance by the Integration Readiness Review (IRR) for the Core. This test equipment will be an update to the GSE developed during the Core GCEL qualification testing and design approach verification required to test specific components, subassemblies, or subsystems.

- Flight Unit Special Tools GSE (One (1) Unit)

  - The FM 2 Flight Unit Special Tools GSE will be required to support unique assembly or operations associated with the FM 2. This GSE will be an update to the GSE developed for assembly and operation activities during the FM 2 Test Article and GCEL development phases.

9.2 MAINTENANCE ACTIVITIES

The usage expectations of the SSFF in the USL will foster the need for planning on-orbit maintenance activities to sustain the respective elements' equipment and subsequent operations. Maintenance activities will include those activities that are scheduled and those that are unscheduled. The scheduled activities will include preventive servicing, cleaning, calibration, and periodic inspection and replacement based on thorough analyses of the components, subassemblies, and subsystems and their operating characteristics, capabilities, and design criteria. The unscheduled activities will include the servicing or replacement of components, subassemblies, and subsystems, which are activities not identified as necessary to be scheduled based on an item maintenance analyses or those that occur to perform a scheduled maintenance activity before it is actually planned. The maintenance analysis will be required to be performed on each element of the SSFF to identify the Orbital Replacement Units (ORUs) candidates. ORUs are considered component/subsystem level hardware that can be removed and replaced on-orbit in the USL. The accurate identification of these ORUs will determine the planning and actual accommodation of scheduled maintenance activities for each element of the SSFF. The activities involved in performing a maintenance analysis to identify ORUs will include determining the reliability, maintainability, and availability of each major component, subassembly, or subsystem of each element of the SSFF. The activity to determine the reliability of the components, subassemblies, or subsystems of each element will involve reviewing the operational environments and the design data and/or vendor specifications on each item. Each developer will require operational and design data from the complement developers as well as their own internally-generated information to determine interface and environmental aspects of each item. This information will be reviewed at each of the major milestones/reviews listed in section 5.0, DDT&E, and will include all drawings and interface schematics, materials lists, thermal analyses, structural reports, and environmental extremes to which the items will be subjected. At each major milestone/review, the maintenance analyses will need to be performed to reflect the latest design components to determine the reliability at each phase. The maintenance analyses will be a continuing analyses beginning with the PDR design information and operational inputs as the initial information required, through the realtime on-orbit data analyses and an analyses of the component, subassembly, or subsystem performance. The maintenance analyses will include activities to identify components (ORU candidates) that will require scheduled maintenance activities, identify the maintenance activities to take place, and to determine the

frequency with which the scheduled maintenance activities will be required to be performed or the frequency with which inspections of items will be required on-orbit. The identification of ORU candidates will allow the appropriate lead times estimation for spares provisioning (resupply and stowage on-orbit) to support the activities and functions required by each of the SSFF elements, the identification of maintenance activities will allow the preparation of procedures to be implemented on-orbit, the frequency of activities or inspections will allow the estimation of quantities of spares to be maintained on-orbit for a desired reliability, as well as identify the logistics planning for ground refurbishment of items. A representative list of ORU candidates as determined during the Phase B effort of the SSFF contract is provided in Table 9.2-1. The actual on-orbit inspections will also will identify the unscheduled maintenance activities.

The identification of ground facilities to support the identified ground-based refurbishment activities, and storage and bonding of replacement and refurbished components will also be accomplished to allow facilities and required personnel support planning. The ground-based facilities will include laboratory environments for the reparation of spent equipment returned to the ground after replacement with ORUs on-orbit, and transport back to the ground from the USL. These ground-based refurbishment facilities will have the capability to perform component level verification of the refurbished items for verification activities which do not require special test capabilities (e.g, toxic offgas test capabilities, EMI test capabilities, etc.), and be able to store and maintain the items in a cleanroom environment prior to shipment and stowage in a logistics module for transport back to the USL. The equipment requirements for the refurbishment activities will include the repair equipment, calibration equipment, minor test equipment, and handling equipment. The use of GSE designed over the course of the SSFF development process will be utilized as much as possible to save on further development costs associated with logistics maintenance support.

The determination of the ORUs will be based on a desired level of reliability to be achieved, and since the reliability of any component in general will be reduced as its required operating time is extended, the cost to maintain and make available the component will increase proportionally to increased reliability. The risk is compounded by the unscheduled maintenance activities, and the level of preparedness that is acceptable for these activities with respect to the available crew time, stowage availability on-orbit, and associated costs versus the potential non-operation of the SSFF or any of its elements during a given time before resupply and maintenance. It is evident that trade studies will need to be performed prior to and during the course of the SSFF development to determine the critical path with respect to logistics maintenance activities.

TABLE 9.2-1 CORE RACK ORU CANDIDATE LIST (1 OF 2)

ORBITAL REPLACEMENT UNIT	QUANTITY
THEMAL CONTROL SUBSYSTEM	
- Heat Exchanger	1
- Pump Module Assembly	1
- Coolant Control Valve Assembly	1
- Coolant Return Valve Assembly	1
- Cold Plates	10
- Hose Assembly	19
POWER CONDITIONING AND DISTRIBUTION SUBSYSTEM	
- Manual Circuit Breaker	2
- RPCM	2
- Primary Distribution Box	1
- Essentials Power Supply	1
- Core Power Conditioning Bank	2
- Core Junction Box	2
GAS DISTRIBUTION SUBSYSTEM	
- Gas Supply Module	1
- Hose Assembly	2
- Contamination Electronics	1
DATA MANAGEMENT SUBSYSTEM	
- Video Display/Keyboard	1
- CDROM	1
- Removeable Hard Drive	1
- High Density Recorder	1
- HDR Electronics	1
- Video Processor	1
- CPC Stimulus	2
- Bus Coupler	5
- Cable Assembly	11

TABLE 9.2-1 EXPERIMENT RACK ORU CANDIDATE LIST (2 OF 2)

ORBITAL REPLACEMENT UNIT	QUANTITY
THERMAL CONTROL SUBSYSTEM	
- Coolant Inlet Control Assembly	1
- Coolant Return Control Assembly	1
- Cold Plates	3
- Accumulator Assembly	1
- Hose Assembly	6
POWER CONDITIONING AND DISTRIBTUION SUBSYSTEM	
- Furnace Junction Box	1
- Essentials Power Supply	1
- Furnace Power Distributor	1
- Current Pulsing Equipment	TBD
- Cable Assembly	TBD
GAS DISTRIBUTION SUBSYSTEM	
- Relief Valve Manifold	1
- Gas Supply Valve Assembly	1
- Vacuum Filter	1
- Vacuum Valve Manifold	1
- Vacuum Pressure Sensor	1
- Vacuum Pump	1
- Storage Vessel	2
- Contamination Sensor	1
- Vacuum Accumulator	1
- Hose Assembly	TBD
DATA MANAGEMENT SUBSYSTEM	
- DCMU	1
- Bus Coupler	3
- Cable Assembly	TBD

9.3 SUPPLY SUPPORT

The SSFF will require support supplies to perform the activities of development, maintenance, refurbishment, testing, and verification. The activities to identify and maintain supply support for the SSFF will include the analysis and requirements definition of such supplies as gases, fluids, tools, handling equipment, test equipment, and samples as applicable to each element of the SSFF. The analysis and requirements definition will involve reviewing the design and verification data, operations activities, and training exercises to be performed during each of the major milestones/reviews for the development of the SSFF elements. The emphasis will be placed on the minimization of quantities to reduce costs without impeding the progress of development activities. Adequate supply support will be maintained during the operational duration of the SSFF, and will require continual attention and reviewing of planning documentation and procedures, as well as routine communication between engineering disciplines and logistics disciplines.

9.4 PACKAGING, HANDLING, STORAGE, AND TRANSPORTATION

Packaging, handling, storage, and transportation activities will be required by the SSFF elements to maintain the integrity of the pre-integrated payloads for each flight increment, and to provide adequate protection and control of spares and refurbishment items. The packaging activity will involve reviewing the parts and assembly and integration drawings, and the reviewing of expected and accepted handling procedures provided via input by the DDT&E of each element to determine the optimum packaging of each item and/or the pre-integrated rack assembly during required transportation intervals of the SSFF development process. The packaging activity will also require the development of procedures and subsequent training activities based on these inputs to be utilized by internal personnel for each element and for the integrated SSFF as applicable.

The handling activities will require the review of parts and assembly and integration drawings of each element subassembly to be handled and for the handling GSE, the review of intended design usage and handling criteria from the DDT&E function of each element, training on the GSE required to perform the handling tasks, and the development of handling procedures. Handling will apply to situations including on-site handling as well as handling at remote or other user sites, and at KSC.

The storage activities will include the review of the maintenance analyses, which will include reference to the quantities of flight spares to be maintained on the ground to

support the logistics effort, as well as the storage of GSE not in use. The storage of flight spares will involve the support of a cleanroom environment for those items completing flight qualification. The activities associated with storage will include the review of the maintenance analyses to determine the logistics flow of spares to and from the USL during specific intervals of the SSFF lifetime. The storage of GSE will require the evaluation of the hardware and software usage schedules and logistics schedules.

Transportation activities are closely related to handling activities, and will include transportation from developer site-to-same developer site locations, from developer site-to NASA facilities for testing, training, and integration, and from one developer site to another developer site for GSE transfers and test and checkout activities. These activities involve the review of transportation container drawings, the development of appropriate procedures to accomplish the transportation activities, and appropriate training to the written procedures and handling procedures.

10.0 PRINCIPAL INVESTIGATOR ACTIVITIES

The Principal Investigator (PI) activities to be performed for the SSFF will include the NASA Project Scientist coordination, ground-based research to support the planned experiments to be performed on-orbit in the USL, realtime flight data analyses to interpret the SSFF performance, return flight data (samples) analyses for determination of science progress and benefit, and the maintenance and archival of the data. The NASA Project Scientist will provide coordination between the various PIs utilizing the SSFF to perform specific science objectives. This coordination will involve directing the necessary working group meetings during the course of the SSFF elements development, overseeing the sample characterization and preparation activities (i.e., ground-based research), determining critical path science objectives for the science community utilizing the SSFF, coordinating the science analyses feedback, and maintaining an interface between the SSFF element developers and the PIs.

The ground-based research activities to be performed by the PIs will include the preparation of samples for flight readiness, the characterization of samples to determine comparisons with returned flight samples, the review and training on the SSFF elements operations and capabilities, and the parallel sample processing during the on-orbit sampling. This will involve reviewing documentation to understand the operations and capabilities of the design of each element affecting their science objectives, traveling to element developer sites and NASA sites to undergo the necessary equipment training, receiving and maintaining duplicate hardware and software sets of SSFF equipment to perform the necessary sample activities, and supporting the realtime mission operations in conjunction with parallel sample processing.

Realtime flight data analyses, returned sample analyses, and the archiving and maintenance of processing data will include reviewing the operations documentation and participating in mission training and simulations to become familiar with the operations protocol, receiving and analyzing realtime temperature and translation data, receiving and analyzing samples returned from orbital processing for comparison with ground-based processing samples, and maintaining and archiving all data for comparison and future analyses for flight operations upgrades to improve the science feedback as applicable to specific samples and their characteristics.

11.0 RISK ASSESSMENT SUMMARY

This section provides an overview of some potential risks associated with the development of the SSFF. Risks and their impacts were briefly addressed in the DDT&E section (5.0) and the Logistics section (9.0), concerning the development of hardware and software within available design resources of each program, and the development of hardware and software sets to support complement program efforts, respectively. . The primary impact of any risks taken with flight equipment development is, of course, the cost impact. Scheduling a critical path of hardware and software development, as well as identifying and emphasizing specific technical proficiency and technology development to support the critical path schedule, will incur risks that could, if manifested, drive the cost of each elements' program development beyond their intended apportionments. Critical path scheduling risks include those items that are absolutely essential for the SSFF development but may not be available because of shared use, manufacturing lead time, inadvertent damage, product discontinuation, etc. Technical/technology risks include those that arise when the current state-of-the-art hardware or software cannot achieve the desired capability or performance required. Potential risks identified as a result of the previous Phase B work on the SSFF, as well as potential risk areas of concern determined in preparing this plan, will be addressed in the following paragraphs.

During the Phase B effort, the GDS was identified as a necessary Core subsystem as referenced in the section 5.0. The GDS has two basic functions; distribution of process gases to the furnace modules and evacuation of the furnaces via the Space Station Freedom Vacuum Exhaust System (SSF VES). So that the contaminants from the furnace modules can be qualified on-orbit, a Contamination Monitoring System (CMS) is being planned for the GDS. The CMS development is considered a risk item since the SSF has imposed stringent waste gas venting requirements for the payloads and in many cases, the sample and furnace materials are not known at this time. This system's function is to qualify the effluents, report this information to the SSF DMS, and thereby receive approval from the SSF VES to vent the waste to the SSF if these effluents are within the specification limits imposed by the SSF. The CMS will also serve as a redundant system for furnace ampoule failure detectors. While a wide range of analytical instrumentation has been developed for space and/or military applications, the CMS is viewed as a risk item since PIs have not been selected and possible furnace and sample materials cannot be identified at this time. In order for the system to be tailored to the furnaces, ground characterization of the furnaces must be done so that the effluents anticipated can be identified to configure the CMS for

footprint identification. Also, the CMS will serve as the monitoring system to safe the furnace on orbit if an anomaly should occur by detecting off-nominal gases for that furnace module and reporting this information to the SSF DMS for direction of corrective action.

During the Phase B effort the TCS was identified as a Core subsystem to interface with the SSF. The TCS dissipates the heat rejected from the SSFF subsystems and furnace modules. The majority of cooling is in the form of water cooling, requiring coldplates for the avionics boxes. While a family of standard coldplates is available from SSF, several of the avionics boxes currently planned for SSFF will require custom coldplates due to size or mounting pattern incompatibilities and/or thermal flux requirements. Custom coldplates will be designed and developed for these items which could increase the duration and subsequent costs originally intended for this subsystem development.

Quick disconnects in the TCS are used for the cooling line inlet and outlet interfaces to the furnace modules, TCS ORUs, and subsystem components. Quick disconnects are considered a risk item, due to the need for zero leakage and minimal air entrainment during mating and demating. SSFF will utilize SSF's QD technology as it evolves. If the technology must be developed by the SSFF, a major schedule and cost impact will be incurred for this development. Another factor that will impact the cost is the required reliability of the QDs against leakage and minimal air entrainment . As addressed in section 9.0, Logistics, depending upon what is deemed acceptable with respect to reliability of equipment on-orbit during physical interfacing and subsequent verification to maintain the SSFF as a safe and functional facility, the cost will be affected proportionally with increased reliability.

One of the primary functions of the Core PCDS is to convert incoming power from SSF and distribute that power to the furnace modules. Power modules for heater element control running off 120VDC supplies have not been flown. Previously flown flight qualified power modules would increase the volume and the weight of the the system by adding 120VDC to 28VDC converters and are themselves larger. Also, the efficiency of the power modules would be decreased if current systems were used. The Phase B study did not identify any reason to doubt flight certification, but EMI compatibility is very difficult.

Solid State switches, referred to as Remote Power Controllers (RPC) in the PCDS concept report is a fairly new technology. As mentioned with the power modules, a risk is incurred when the design of a system is based on unqualified hardware.

The Core Junction box for the SSFF PCDS is based on the use of flexible high powered printed circuit boards with integrated surface mount connectors as opposed to the traditional terminal blocks. This is relatively new technology for space application and is considered a risk since the concept and hardware will involve development and test of a system employing this technique as well as flight qualification.

The current pulsing concept must be developed. The system must be able to supply a large amount of energy, several times within a short time period. SSFF has followed the development of this hardware with the Crystal Growth Furnace (CGF) and will employ their concept as it is more defined and developed. Due to the status of the system, it is considered to be a risk item for the SSFF PCDS. Also, it could impact power draw of the facility.

The SSFF DMS concept is based on double mounting as opposed to single side mounting of cards on a board. This technique for mounting has not been utilized in space and will require development and flight qualification. Therefore, it is considered to be a risk item for the SSFF DMS.

The high density recorder for the SSFF DMS is understood to have relatively low reliability and poses a risk on the system operation and accommodation of the experiment modules. This unit will have the function of storing experimental data which is being generated by the experiment modules.

The SSF interfaces to the DMS are not settled at this time. The SSFF assumes a Network Interface Unit (NIU) will be provided as a board that can be incorporated in the SSFF Core Computer. This unit will provide the interface for downlink, uplink, health and status monitoring, and request for services to SSF. Change in this interface could increase the development time and cost for the software development and hardware development associated with this system.

Ground logistics and flight logistics (see section 9.0 Logistics) pose a risk. Section 9.0 demonstrates the importance of the logistical process for the SSFF and describes the

importance of the flow between the Core developer and the Furnace Module developers. A risk is associated with the entire logistical flow since the Core and the Furnace Module developers will depend on each other for integration, verification, ground support equipment, schedule, and others. The logistical plan included in section 9.0, is geared towards minimizing the interface incompatibilites that will arise during the design and development process, and thus, increasing the reliability of interfaces by minimizing duplication of effort. The logistical plan is at the expense of developing multiple hardware and software sets versus system reliabilty for on-orbit, as well as, ground processing activities. An assessment is required to determine the cost of implementing a logistics plan, including hardware and software duplication for higher reliability interface compatibilities, versus the cost of duplicating DDT&E effort between programs and determining independent interface designs and their impacts.

The maintenance philosophy for the SSFF has not been established and, therefore, the Orbital Replacement Units (ORUs) required on orbit or the spares required on the ground cannot be assessed without assumptions for the maintenance philosophy. This could pose definite schedule impacts since the carriers to and from the SSF may not be frequent enough to resupply the facility with spares and may not be frequent enough for on-orbit repair by the crew. Recommend that the Phase C/D perform a detailed trade between reliability and logistical resupply to establish this maintenance philosophy

An on-orbit verification and installation plan for payloads to be installed in the SSF (USL) is not in place at this time, nor has it ever been accomplished for complex facilities such as the SSFF. This new area of technical complication will have many programmatic and schedule risks that will affect the cost of developing the SSFF..